
Geological Survey of Canada
Commission géologique du Canada

PAPER 85-10

**WINDSOR GROUP SALT IN THE MINAS SUBBASIN
OF NOVA SCOTIA**

R.D. Howie

1986

Canada

86-04233/



**Geological Survey of Canada
Paper 85-10**

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Available in Canada through

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Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Canada K1A 0E8

3303-33rd Street N.W.,
Calgary, Alberta T2L 2A7

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M44-85/10E Canada: \$4.00
ISBN 0-660-12086-0 Other countries: \$4.80

Price subject to change without notice

Critical Readers

J.S. Bell
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Original manuscript submitted - 1984 -06
Final version approved for publication - 1985 - 01

CONTENTS

1	Abstract/Résumé
1	Introduction
1	Acknowledgments
1	Regional Geology
2	Windsor-Kennetcook and Beaver Brook areas
2	Shubenacadie-Stewiacke area
4	Structural Geology
4	Tectonism
5	Salt Dissolution and Preservation
5	Summary
5	Bibliography
	Figures
7	1. Distribution of Windsor Group salt, Atlantic Provinces and Gulf of St. Lawrence
8	2. Geological map of the Windsor-Truro area of Nova Scotia
9	3. Distribution of Windsor-Group salt in the Windsor-Truro area of Nova Scotia
10	4. Bouguer Gravity Anomaly map of the Windsor-Truro area of Nova Scotia
11	5. Geological map eastern Minas subbasin, Nova Scotia
12	6. Composite Mississippian and Pennsylvanian succession, Minas subbasin, Nova Scotia
13	7. Isopachs of Carrolls Corner formation, Minas subbasin, Nova Scotia
14	8. Isopachs of Stewiacke formation, Minas subbasin, Nova Scotia
15	9. Stewiacke formation salt analysis from three boreholes, Stewiacke graben, Minas subbasin, Nova Scotia
16	10. Isopachs of MacDonald Road formation, Minas subbasin, Nova Scotia
17	11. Isopachs of Green Oaks formation, Minas subbasin, Nova Scotia
18	12. Isopachs of Watering Brook formation, Minas subbasin, Nova Scotia
19	13. Isopachs of Scotch Village formation, Minas subbasin, Nova Scotia
20	14. Cross-Section A-A', Minas subbasin, Nova Scotia
22	15. Cross-Section B-B', Minas subbasin, Nova Scotia
23	16. Structure contours on Stewiacke formation, Minas subbasin, Nova Scotia
24	17. Structure contours on upper salt MacDonald Road formation, Minas subbasin, Nova Scotia
25	18. Borehole locations, Stewiacke area, Minas subbasin, Nova Scotia
26	19. Gravity map, Stewiacke area, Minas subbasin, Nova Scotia
27	20. Aeromagnetic map, Stewiacke area, Minas subbasin, Nova Scotia
28	21. Effects of Maritime disturbance on the Cobequid uplift and adjacent areas
29	22. Salt dissolution model, Stewiacke graben, Minas subbasin, Nova Scotia

WINDSOR GROUP SALT IN THE MINAS SUBBASIN OF NOVA SCOTIA

Abstract

The Paleozoic fold belt of Atlantic Canada forms the northeastern part of the Appalachian Mountains. Within the fold belt, the Carboniferous Windsor Group includes the only marine rocks of Late Paleozoic age in southeastern Canada. The Windsor Group evaporites, preserved on land in outliers or as part of a northeast trending basin under the Gulf of St. Lawrence, form part of a much larger depositional area, the Magdalen Basin. Based on present structural trends, the Magdalen Basin has been divided into subbasins of which the Minas subbasin is one.

The structural and depositional history of the Windsor Group in the Minas subbasin has been determined through a detailed study of the evaporite sequence. Salt occurs as bedded deposits or flow structures that vary in thickness from a few centimeters to 300 m. The present distribution and thickness of the salt can be attributed to the environment of deposition or tectonism, or both.

Résumé

La zone orogénique paléozoïque de l'Atlantique canadien forme l'extrémité nord-est des Appalaches. À l'intérieur de cette zone, le groupe carbonifère de Windsor contient les seules roches d'origine marine du Paléozoïque récent dans le sud-est du Canada. Les évaporites du groupe de Windsor, qui se présentent sur terre sous forme de buttes-témoins, ou dans un bassin à orientation nord-est qui se trouve sous le golfe Saint-Laurent, font partie d'une zone de sédimentation beaucoup plus vaste, le bassin Magdalen. D'après les tendances structurales actuelles, le bassin Magdalen a été divisé en un certain nombre de subbassins dont le bassin Minas.

L'histoire structurale et sédimentaire du groupe de Windsor dans le subbassin Minas a été reconstituée grâce à une étude détaillée de la séquence d'évaporites. Le sel se présente sous forme de gisements stratifiés ou de structures fluidales dont l'épaisseur varie de quelques centimètres à 300 mètres. La répartition et l'épaisseur actuelles du sel sont attribuables au milieu de sédimentation, au diastrophisme ou aux deux.

INTRODUCTION

In recent years exploratory drilling, geological mapping and geophysical surveys on land and in the offshore have added to our knowledge of the stratigraphy and structure of the Windsor Group in the Magdalen Basin. This basin, with the main depocentre beneath the Gulf of St. Lawrence, extends into Nova Scotia, New Brunswick, Prince Edward Island and western Newfoundland (Fig. 1)¹. These onshore extensions have been designated as subbasins (Geological Survey of Canada Map 1400A); the Minas subbasin is one of these.

Early workers placed the salt sequences near the base of the Windsor Group and believed that only one salt-rich interval was present. More recently it has become apparent that several separate salt intervals occur locally higher in the section. Stratigraphic problems still remain because, in many of the areas where studies have been undertaken, the salt is highly deformed. Halokinetic structures such as pillows, domes, diapirs, anticlines, ridges and salt walls are present, and their post-depositional flowage often makes it difficult to reconstruct the original stratigraphy.

In the Minas subbasin, which is an isolated marginal depression or outlier of the Magdalen Basin, bedded and deformed salt are present. In this paper, the distribution and geometry of the Windsor Group salt deposits are illustrated on surface geological maps, isopach maps, structure contour maps and cross-sections. Since interpretations depend in part on regional geophysical data, gravity and magnetic maps are also included.

Acknowledgments

The author is particularly grateful for information provided by P.S. Giles and R.C. Boegner of the Nova Scotia Department of Mines and Energy; D.E.T. Bidgood and K. Howells of the Nova Scotia Research Foundation Corp.; G. Karg, Canadian Oil and Gas Lands Administration, Department of Energy, Mines and Resources. Special thanks

are also extended to Geological Survey colleague B.V. Sanford and D. Umpleby (formerly with G.S.C.) for assistance and advice. The author also wishes to thank J.S. Bell, P.S. Giles and G.L. Williams critical readers and M.P. Latremouille and J. Watt technical editors.

REGIONAL GEOLOGY

In the Windsor-Truro area of the Minas subbasin, basement is defined to include (Fig. 2) rocks ranging in age from Precambrian to Early Devonian that have undergone regional metamorphism, granitization, intrusion or intense deformation during or prior to the Acadian Orogeny (Poole, 1967). The cover sequence of overlying Upper Paleozoic and Mesozoic sediments range in age from Middle Devonian to Early Cretaceous (Howie and Barss, 1975a; Keppie, 1979).

The oldest Upper Paleozoic rock unit in the area is the Horton Group. It was originally defined by Bell (1929) from outcrops on the west side of the Avon River, near Windsor, which were dated as Tournaisian. In 1967 Kelley recognized the Horton Group as a stratigraphic rock unit, essentially the same as Bell, except for the removal of an Early Mississippian (Tournaisian) time restriction. The Horton Group is a variable clastic sequence of conglomerates, sandstones and shales which directly overlies basement. It is interpreted to have accumulated under continental conditions in environments ranging from piedmont to fluvial-lacustrine (Howie and Barss, 1975a). Most Horton Group rocks are Early Carboniferous (Tournaisian) but some are as old as Middle Devonian and as young as Viséan.

The Windsor Group (Middle and Lake Viséan age; Howie and Barss, 1975a) overlies the Horton Group and onlaps the pre-Carboniferous basement. The rocks in the group record a marine incursion into the Maritime region. In most areas basal Windsor Group contacts are conformable or disconformable but, locally, there are angular unconformities. At the type section on the Avon River (Bell, 1929, 1958), the Windsor Group is composed of red

¹ Figures appear on pages 7 through 29.

sandstone, red and minor grey siltstone, limestone, minor dolomite and gypsum. The soft nature of these sediments combined with folding, faulting, overturning and brecciation have rendered the stratigraphic section difficult to interpret. Based entirely on faunal evidence obtained primarily from the carbonates, Bell divided the entire Windsor section into subzones, A to E. The thickest evaporite zones were attributed to subzones A and B, with most of the limestone horizons included in subzones, C to E. Although salt was known to be present in the Windsor Group, it was not included as part of the type section because it was not exposed at the surface.

The gradual withdrawal of the Windsor sea due to regional uplift represented a transition from marine through brackish to a fluvial and fluvial-lacustrine environment of deposition. The overlying Canso Group (Namurian A) as described by Bell (1944) from the Strait of Canso area, Nova Scotia, consists of thinly laminated, nonmarine, red and green shale, sandstone and minor limestone. Exploratory drilling indicates salt is also locally present in the Canso Group.

The Riversdale Group (Late Namurian to Early Westphalian A age), described by Bell (1944) from Riversdale, Nova Scotia, consists of continental deposits of red and green sandstone, siltstone and shale. Coal and conglomerates are also locally present in some areas (Howie and Barss, 1975b; Poole et al., 1970).

The Pictou Group (Westphalian B to Wolfcampian; Howie and Barss 1975b) was described by Bell (1944) from Joggins, Nova Scotia. It is a nonmarine sequence of red and grey sandstone, arkosic grit, shale, mudstone and local, economic deposits of coal. It rests unconformably on older Paleozoic rocks and onlaps basement.

The Triassic rocks of the Bay of Fundy-Minas Basin area of Nova Scotia, as described by Powers (1916), can be considered as an intertonguing complex of continental redbeds and basalt. Designated the Fundy Group by de Vries Klein (1962), the sequence can be divided into informal units consisting of three general zones: a basal unit composed of red sandstone, shale and conglomerate; a middle basalt zone; and an upper limestone-claystone sequence. When the Fundy Group was redefined by Donohoe and Wallace (1982), the basalt was shown to be partly Triassic and partly Jurassic. The limestone-claystone sequence above the basalt was mapped as Early Jurassic.

In the Musquodoboit area, Cretaceous sediments unconformably overlie Upper Paleozoic rocks (Stevenson and McGregor, 1963; Lin, 1971; Giles and Boehner, 1979). This section contains red and grey kaolin, silica sand and lignite.

Based on surface mapping and borehole data (Fig. 3), the salt in the Windsor Group rocks of the Minas subbasin has been divided into two categories:

1. Structurally disturbed salt located in the Windsor-Kennetcook and Beaver Brook areas.
2. Bedded salt located in the Shubenacadie-Stewiacke area.

Windsor-Kennetcook and Beaver Brook areas

In the Windsor-Kennetcook and Beaver Brook areas 12 boreholes are known to have intersected Windsor Group salt. The well name and salt thickness in each well is shown on Figure 3. The thickness of the salt in borehole locations 4, 6 and 7 is not shown because the salt zone is a mixture of shale and salt or sandstone and salt. The borehole data provided by the operating companies for each well shown on this map indicate that the Windsor Group rocks are highly disturbed, which makes it very difficult to reconstruct a detailed stratigraphic section for the area.

The structural complexity of the Carboniferous rocks in this part of the Minas subbasin was also observed by Boyle (1963) and illustrated on his map on the Walton-Cheverie area. If all the faults recorded on Boyle's map were transferred to the geological map in this report (Fig. 2), their traces would obliterate almost all other information. If the remainder of the area from Windsor to Beaver Brook were mapped in the same detail as the Walton-Cheverie area, an equivalent number of faults would probably be recognized. The large number of faults that cut the Carboniferous rocks can be attributed to a highly shattered basement overlain by a fairly thin sedimentary cover through which many of the basement faults penetrate. The movement of groundwater along the faults has led to solution of Windsor Group salts and caused further collapse.

The Bouguer gravity anomaly map of the Windsor-Truro area (Fig. 4) indicates a 5 to 15 mgal gravity contrast over the Windsor-Kennetcook area. As about 10 mgal of the 15 mgal anomaly is centred along the southeast side of the Windsor outlier, adjacent to a basement topographic high, most of the anomaly can probably be attributed to variations within the basement complex, or to the overlying sediments. The gravity anomaly in the Beaver Brook and Shubenacadie-Stewiacke areas also appears to be more closely related to variations within the basement complex than to the cover rocks that contain some low density sediments.

Shubenacadie-Stewiacke area

The Shubenacadie-Stewiacke area contains the least disturbed Windsor Group evaporite section observed so far in Nova Scotia (Fig. 5). Stratigraphically, the Upper Paleozoic rocks which unconformably overlie the pre-Carboniferous basement, in ascending order belong to the Horton, Windsor, Canso and Pictou groups. The map and composite lithologic section (Fig. 6), compiled by Giles and Boehner (1979) contain a number of informal names. The mechanical log to the left of the stratigraphic column is a composite section from a number of wells drilled in the area by St. Joseph Explorations Ltd.

The Carboniferous rocks are contained within the shallow, northeast trending Stewiacke graben, named herein after the nearby town of Stewiacke. As shown in Figure 2, the Stewiacke graben is an offset of axial normal faults believed to be related to its subsidence. To the west and north of Shubenacadie, thrust faults and overturned beds are present.

The Horton Group is a fining upward sequence of conglomerate, grit, sandstone and siltstone in which the coarser grained fractions are predominant (Stevenson, 1959). The Macumber Formation is the basal member of the Windsor Group and it records the earliest known Carboniferous marine invasion of Nova Scotia. It lies concordantly upon the upper sands and shales of the Horton Group but, where it oversteps the Horton Group, it lies with pronounced angular unconformity on pre-Carboniferous basement (Giles and Boehner, 1979). The Macumber Formation is somewhat variable in lithologic character, but it typically consists of limestone or dolostone, is variably fossiliferous, and generally ranges in thickness up to 6 m (Geldsetzer, 1978; Giles and Ryan, 1976; Schenk, 1967; Stevenson, 1959).

The Macumber Formation is overlain by the Carrolls Corner formation¹, which is considered to correlate with the 'basal anhydrite' known throughout Atlantic Canada (Giles and Ryan, 1976). This anhydrite facies, which has a remarkably uniform lithology over a wide area, contains minor intercalations of grey-green, argillaceous dolostone and siltstone at irregular intervals. These impurities can be used locally for correlation, although they are not sufficiently distinctive to constitute marker beds.

¹ The terms Carrolls Corner, Stewiacke, MacDonald Road, Green Oaks and Watering Brook formations are informal terms from Giles and Boehner, 1979.

Data from at least seven boreholes were used to compile an isopach map of the Carrolls Corner formation and each of the overlying Carboniferous formations as shown on Figure 6. Most of the wells are clustered along the southern and western sides of the shallow Stewiacke graben, with only a few wells in the central part of the graben, and along the southeast, north and northwestern flanks. As very few of the boreholes penetrated the entire Carboniferous section, and as the wells are not evenly distributed throughout the map area, some of the isopachs are of necessity, highly interpretative.

In the isopach map of the Carrolls Corner formation (Fig. 7), the hachured zone delineates the outcrop areas where some of the rocks have been partly removed by erosion. From Elmsdale to Shubenacadie, the isopach lines indicate the area contains in excess of 300 m of anhydrite. The contour interval is 200 feet. Locally, in the Gays River area, exploratory drilling has penetrated up to 400 m of anhydrite (Giles and Ryan, 1976). In the Stewiacke area the contours indicate about 180 m of section. Although there is very little well control east of Stewiacke, the area is shown to contain at least 300 m of anhydrite, as it is considered to be equivalent to the section in the Elmsdale-Shubenacadie area. In the overthrust area, northwest of Shubenacadie, the 400 foot contour is based on a single borehole that was completed as a basement test. The contour line is shown to pass through the thrust fault zone without being deflected, because the thrust fault is considered to only affect some of the younger overlying beds (P. Giles, 1979, personal communication).

Along the south side of the basin where the Carrolls Corner formation forms the bedrock surface, the anhydrite is hydrated to gypsum. The surface expression of this alteration is identified by numerous sinkholes filled with water which formed a karst topography. In the Truro area, Stevenson (1958) suggested the gypsum-anhydrite altered zone may extend to a depth of 23 m. In the Wentworth Gypsum Quarry, however, near Windsor (western part of Minas subbasin), groundwater has only altered the upper 9 m of anhydrite to gypsum (R. Moore, 1980, personal communication). In the Shubenacadie-Stewiacke area surface exposures are usually hydrated to a depth of at least 10 m (Giles and Bohner, 1979).

The Stewiacke formation, which overlies the Carrolls Corner formation, is the main salt zone of the Windsor Group in the Minas subbasin. The nearly horizontally bedded salt interval (Fig. 8) varies in thickness from a few metres to 300 m. The thickest section is around the town of Stewiacke. The salt varies in colour from grey through orange to translucent, and is interbedded with anhydrite in the lower two-thirds of the formation and green siltstone in the upper third. Chemical analyses and sidewall densilogs have been plotted alongside the lithologic log of the salt for the Stewiacke Borax No. 1 borehole and the St. Joseph Explorations Ltd. 153-1 and 153-3 wells, in order to illustrate the purity of the salt in the central part of the Stewiacke graben (Fig. 9). An interpreted area of erosion and possible dissolution around the perimeter of the deposit is indicated by the hachured area. This zone, containing unleached material from the Stewiacke Formation and rock fragments from overlying or adjacent formations, constitutes a residual breccia.

As salt with a purity of 95% NaCl is the minimum industrial shipping grade, datum line was plotted from the densilogs. A comparison of the three wells, indicated that the lower 60 m of the Stewiacke Borax No. 1 borehole and the St. Joseph Explorations Ltd. 153-3 had an in situ purity of 93% NaCl (Giles and Bohner, 1979). The upper 60 m of the St. Joseph Explorations Ltd. 153-1 well is also a fairly pure salt zone with a few beds of anhydrite. If the anhydrite beds

die out laterally, this horizon may also contain as much salt as the lower beds in the other two wells. The evaporite zone was also tested for potash, but the results indicated little promise for this mineral (Boehner, 1980).

The Stewiacke formation is overlain by the MacDonald Road formation. At the top of the Stewiacke formation, an anhydrite, red siltstone breccia, which was encountered in the St. Joseph Explorations Ltd. 153-4, 116-1 and 117-2 wells (Fig. 8), has been interpreted to indicate a period of subaerial erosion prior to the deposition of the MacDonald Road formation (Giles and Bohner, 1979).

The MacDonald Road formation is a complex succession of interbedded anhydrite, gypsum, salt, limestone, dolomite, siltstone and fine grained sandstone. This transgressive and regressive marine sequence has, as its dominant rock type, anhydrite. It also contains a number of lithologically distinct carbonate members together with two or three, thin salt horizons, as shown on the stratigraphic column (Fig. 6) and in the St. Joseph Explorations Ltd. No. 153-3 borehole (Fig. 15).

As indicated on the isopach map (Fig. 10), most of the Stewiacke graben area contains 120 to 180 m of MacDonald Road sediments. Boreholes in the overthrust area northwest of Shubenacadie penetrated between 80 to 180 m of sediments. This area was not contoured, due to insufficient data in what is probably a tectonically complex zone. Although few stratigraphic data are available for the highly faulted zone north of Stewiacke, the area is tentatively shown to contain in the order of 180 m of section.

The Green Oaks formation overlies the MacDonald Road formation with paraconformable or disconformable contacts. It is a complex succession of red and green siltstone, marine carbonates and minor evaporites. Although the lithology resembles the MacDonald Road formation, with evidence of repeated marine transgressions and regressions, it contains more arenaceous and argillaceous material.

As indicated on the isopach map (Fig. 11) the Green Oaks formation in the Stewiacke graben has a mean thickness of slightly over 120 m. In the overthrust area west of Shubenacadie, boreholes penetrated up to 145 m of sediments. This area was not contoured because of insufficient data in the overthrust zone. The highly faulted area north of Stewiacke contains about 550 m of sediments (Giles and Bohner, 1979).

The overlying Watering Brook formation (Giles and Bohner, 1979) represents the Canso Group in the area (Fig. 6). This sequence of interbedded siltstone, fine grained sandstone, anhydrite, and gypsum conformably overlies the Green Oaks formation. Based on borehole data, the formation is estimated to be up to 180 m thick at Stewiacke and 245 m thick east of Stewiacke as indicated by the isopach map (Fig. 12). On this map the hachured area represents the present distribution of the Watering Brook formation, except in the area east of Stewiacke that is overlain by younger sediments.

The Scotch Village Formation which represents the Pictou Group in this area (Howie and Barss, 1975a), unconformably overlies the Watering Brook formation. It consists of thinly bedded siltstone, fine- to medium-grained sandstone, minor coal, and plant debris. The Scotch Village Formation is 60 to 90 m thick and is only present in a small area east of Stewiacke as indicated on the isopach map (Fig. 13).

Semi- to poorly-consolidated sediments that locally overlie the Carboniferous rocks with angular unconformity (Fig. 5) have been dated as Early Cretaceous (Stevenson, 1959). The Early Cretaceous section in the area north of Stewiacke, contains stratified layers of nonmarine clay, sand, silt, and lignite rich in pyrite. Although the

details of individual beds are unknown due to the thick mantle of drift, a 12 m section of fire clay has been excavated beneath 5 m of drift on the southern outskirts of Shubenacadie. Much of the original Lower Cretaceous section has probably been removed by erosion or scoured by the advancing ice sheets prior to the deposition of the Pleistocene to Recent glacial material (Sevenson, 1958).

STRUCTURAL GEOLOGY

Well data and surface geology have been used to construct two highly generalized cross-sections (Fig. 14 and 15), that serve to illustrate the lithologic character and structural configuration of the rocks in this area. Although the Upper Paleozoic rocks are relatively flat-lying, the vertical exaggeration of about 20 to 1 used in the preparation of the sections has substantially increased the apparent dip of the beds. One of these figures is a very generalized northeast trending section along the axis of the shallow Stewiacke graben (Fig. 14). The general location is shown on the index map. The southwestern end of this section has been extended across a fault to include the southern flank of the basin. The salt (Stewiacke formation) at this end of the section is terminated by a breccia zone.

On the northeastern side of the section, the St. Joseph Explorations Ltd. 153-3 borehole penetrated salt in the Stewiacke, MacDonald Road, and Watering Brook formations. The thin salt beds in the lower part of the Watering Brook formation appear to represent only a locally preserved facies. Two of the three thin salt zones with related stratigraphy associated with the MacDonald Road formation in the 153-3 borehole have also been recognized in the Stewiacke Borax No. 1 borehole, which suggests the sequence can be correlated locally.

The Stewiacke formation in borehole 153-3 appears to be fairly thin, compared with some of the other boreholes in the area, if the anhydrite at the bottom of the hole is assigned to the underlying Carrolls Corner formation. However, if the anhydrite zone is interpreted as a lens within the Stewiacke formation, additional salt may be present beneath it.

B-B' is a north-south cross-section (Fig. 15) with borehole 153-3, in common with the previous section. Although the beds in this section also dip at a few degrees from horizontal, the vertical exaggeration required to plot section A-A' and B-B' at the same scale has greatly oversteepened the beds.

The Stewiacke formation at one time presumably occupied a much larger area than at present. Prior to the deposition of the MacDonald Road formation, the period of subaerial erosion that removed part of the Carrolls Corner formation (Giles and Boegner, 1979) probably also removed salt of the Stewiacke formation. Cross-section B-B' is bounded south and north by faults. During the Maritime Disturbance (Carboniferous to Permian; Poole, 1967), the central core of the Stewiacke graben was downdropped relative to the rest of Nova Scotia platform, thus preserving a large area of bedded salt beneath a substantial thickness of anhydrite, siltstone, and carbonate. Along the perimeter of the graben, most of the salt has probably been removed by erosion and dissolution, as indicated in Figure 8.

A structure contour map on the Stewiacke formation (Fig. 16) indicates that the depth to salt, from the surface, varies from 120 m to 550 m. A structure contour map was also prepared for the upper salt interval in the MacDonald Road formation (Fig. 17). The top of this 12 m salt bed varies in depth from about 120 m to over 365 m. The MacDonald Road formation salt overlies the Stewiacke formation in the Stewiacke area, which appears to have been

a depocentre during the deposition of the Windsor Group. An outline of the two salt zones has been superimposed on a map showing borehole locations (Fig. 18), to indicate the subsurface stratigraphic control in the area. The boreholes have been indexed to show the formations penetrated at each location.

The distribution, thickness, and tectonic setting of the Windsor Group evaporites in the Stewiacke graben to some extent appear to have influenced the gravity and aeromagnetic signature of the area. The outline of the Stewiacke formation salt has been superimposed on a detailed gravity map of the area (Fig. 19). Although this is a relatively shallow sedimentary feature, there is a 20 mgal gravity contrast between the minima in the centre of the Stewiacke graben and the maxima along the basement outcropping to the south. The variation in the gravity data appears to have been determined by the depth and thickness of the salt, and the nature of underlying and overlying strata. The gravity contour adjacent to borehole 153-3 indicates a slight increase in density, rather than a decrease which would be expected along the axis of the salt basin. This increase may be attributed to an anomaly within the basement or a local basement high. If the anhydrite in the lower part of this borehole is considered to be part of the Carrolls Corner formation rather than a local facies of the Stewiacke formation, the gravity anomaly may represent a basement high.

The elongate gravity low along the edge of the salt deposit, north of borehole 153-3 and the small gravity low, north of Stewiacke on the east side of the Shubenacadie River, suggest an increase in the thickness of the sedimentary section adjacent to a fault zone. The gravity low at Shubenacadie is also attributed to an increase in depth to basement.

The outline of the Stewiacke formation salt was also superimposed on the aeromagnetic map of the area (Fig. 20). The masking effect of sediments in a shallow graben on the magnetic contours is clearly shown.

TECTONISM

Post-Windsor Group tectonism, generally referred to as the Maritime Disturbance (Poole, 1967) reactivated many of the faults formed during the Acadian (Devonian) Orogeny. Figure 21, a tectonic map of the Minas and Cumberland subbasins, shows the effects of the Maritime Disturbance on these subbasins and the Cobequid Uplift. The Cobequid Uplift is a topographically elevated segment of the pre-Carboniferous basement complex that separates the Minas subbasin in the south, from the Cumberland subbasin to the north.

The Nova Scotia platform (Poole, 1967) is shown as basement on the southern part of Figure 21. In the Shubenacadie area, the Upper Paleozoic rocks are contained in a depression of the Nova Scotia Platform, where they were relatively unaffected by basement adjustments related to the Cobequid Uplift. Here, near-horizontal bedded salts underlie an area of about 620 km². The remainder of the Upper Paleozoic rocks in the Minas subbasin are shown as affected by the Cobequid Uplift. Although the Cumberland subbasin is not part of this study, it has been included, to show that subbasins on both sides of the Cobequid Uplift were affected by tectonism related to this basement block. A to A' (Fig. 21) is a generalized north-south cross-section through the area.

When the Cobequid basement block became a positive feature during the Maritime Disturbance, basement faults were reactivated, and basement blocks readjusted in the Minas subbasin, over a wide zone adjacent to the

Cobequid Uplift. These basement flexures greatly disturbed the overlying Upper Paleozoic rocks, as indicated by the large number of faults mapped between Windsor and Truro. Basement adjustments in this area can be observed at the surface because of the relatively thin sedimentary cover. The movement of groundwater through this fault system has probably dissolved a considerable volume of salt and hydrated anhydrite to gypsum. Both processes will have further disrupted the sedimentary section.

Upper Paleozoic rocks in the Shubenacadie area with a regional dip of less than 3° were virtually unaffected by the Cobequid Uplift because these rocks were deposited on cratonic block, the Nova Scotia Platform. As this part of the platform is now the shallow Stewiacke graben, Windsor Group rocks have been preserved as near-horizontal bedded deposits. Most of the faults mapped in this area are around the sides of the graben. The geological map (Fig. 5) and the southern part of Section A-A' (Fig. 21) both illustrate minor overthrusting and overturning of Windsor Group rocks west and northwest of the town of Shubenacadie. This deformation was probably related to the uplift of a basement ridge west of the Stewiacke graben.

SALT DISSOLUTION AND PRESERVATION

The preservation of salt in many of Windsor Group outliers may be partly attributed to the high silt content in the upper part of the section. The importance of a high silt content in dissolution breccias which lie adjacent to the present salt boundaries is shown in Figure 22. At this location the HP-5, HP-6 and HP-7 (Horne property) boreholes were drilled by Imperial Oil Ltd. (Fig. 8). The HP-6 well in the centre of cross-section C-C' passed through a dissolution breccia, composed of silt with clasts of anhydrite. When the basement was downfaulted to the north, part of the area now occupied by the breccia zone may have contained salt. It is reasonable to infer that water migrating along the fault, and possibly from the Horton Group to the south, dissolved the salt, causing the collapse of some of the overlying anhydrite and carbonate strata as indicated by the steep dips and breccia zones in the MacDonald Road formation, in the HP-6 borehole. Interbeds of siltstone, along with argillaceous material associated with the anhydrite, accumulated in the breccia zone. When the silt impregnated the breccia, it presumably sealed off the salt from further dissolution. Solution breccias high in silt are probably responsible for the preservation of Windsor Group salt in some of the other evaporite deposits in Atlantic Canada.

SUMMARY

The Stewiacke formation of the Windsor Group appears to be the main salt bearing zone in the Minas subbasin of Nova Scotia. It is a near-horizontal bedded deposit, 56 km long, 11 km wide, up to 300 m thick, which is 455 m below the surface in the centre of the basin. Mechanical logs and chemical analysis of a number of holes indicate at least 60 m of the salt section has a purity equal to, or better than, 93%. This occurrence may have potential as a future mineral deposit or for underground storage of hydrocarbons.

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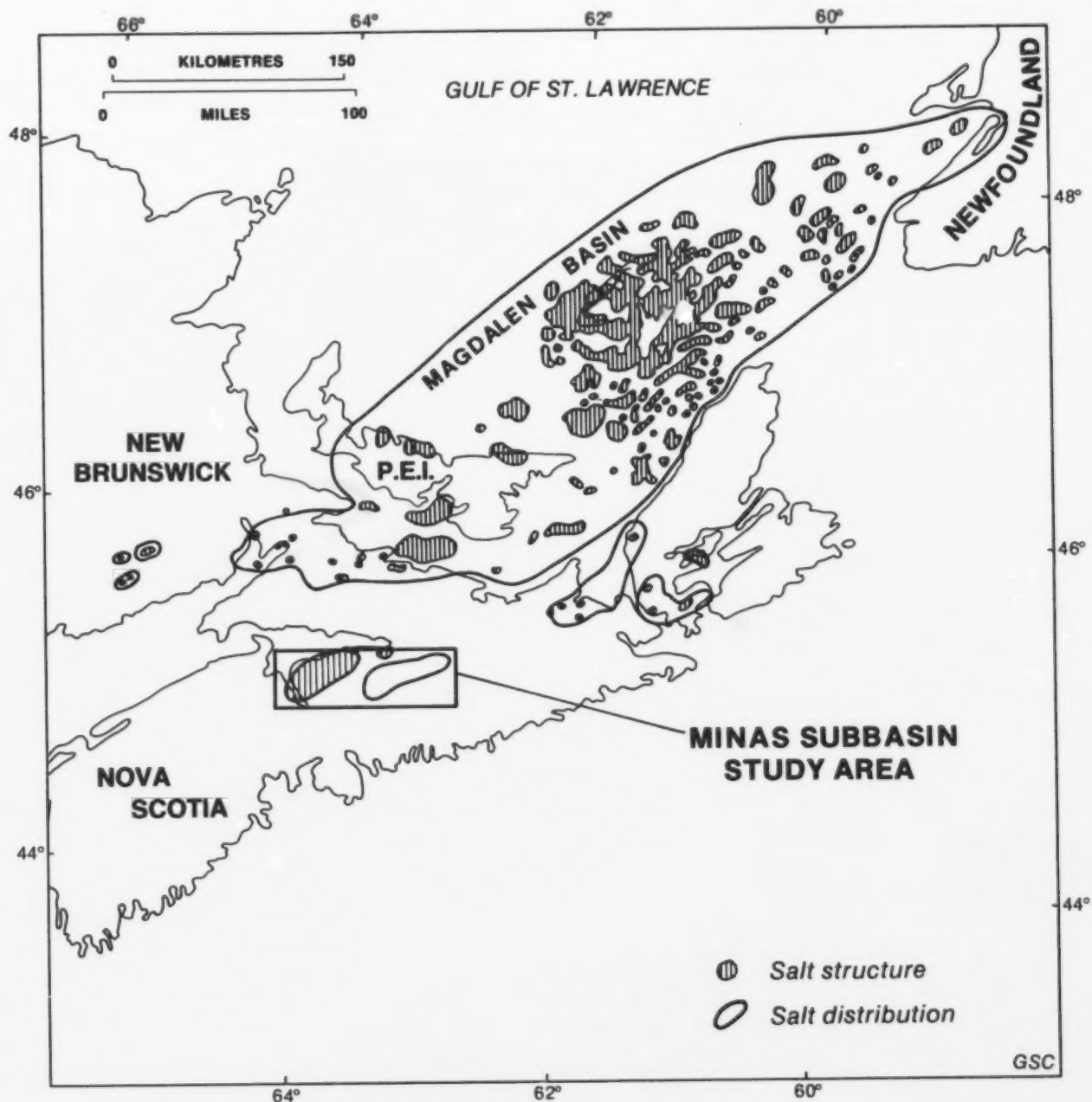


Figure 1. Distribution of Windsor Group salt, Atlantic Provinces and Gulf of St. Lawrence.

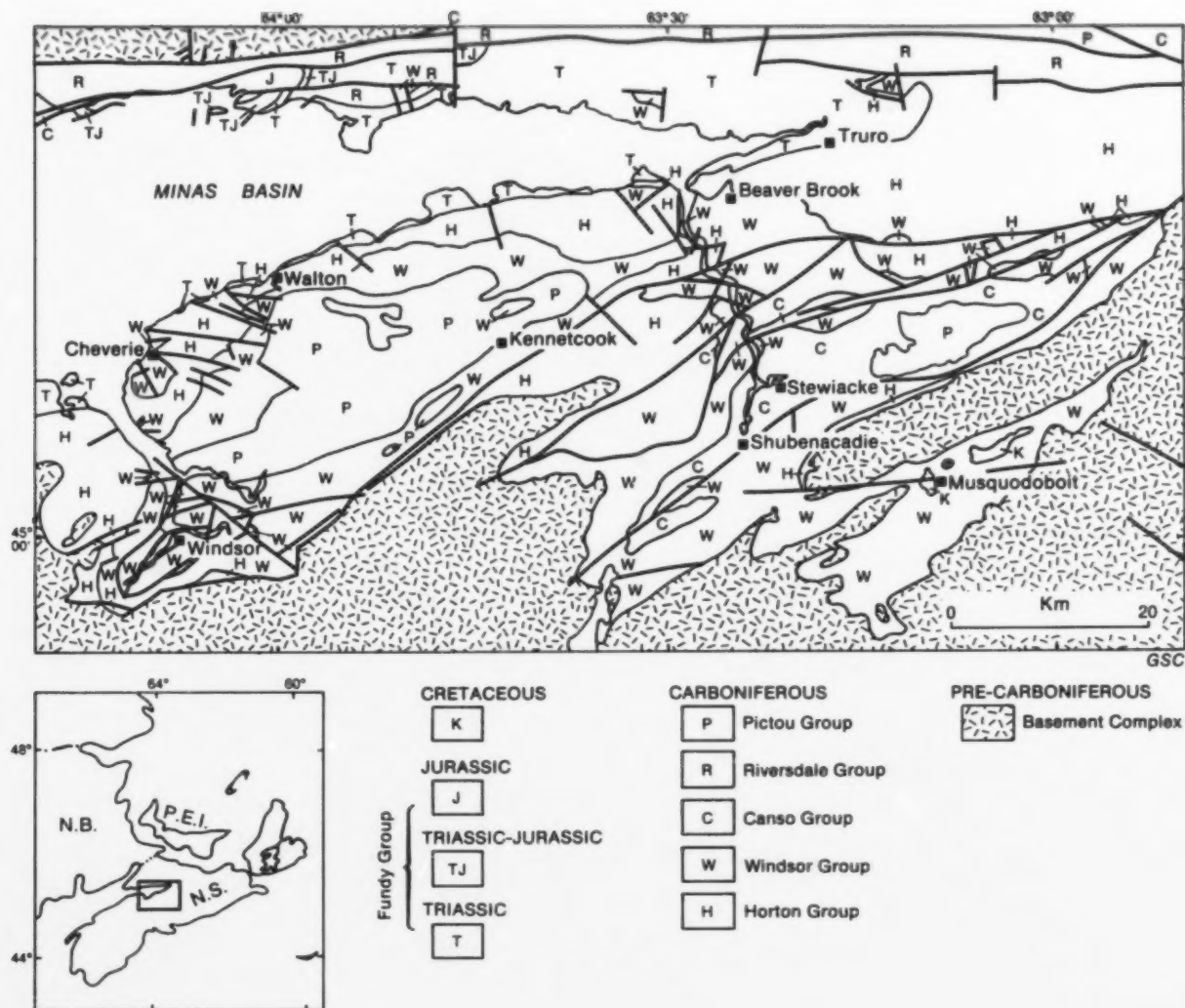


Figure 2. Geological map of the Windsor-Truro area, Nova Scotia (adapted from Keppie, 1979).

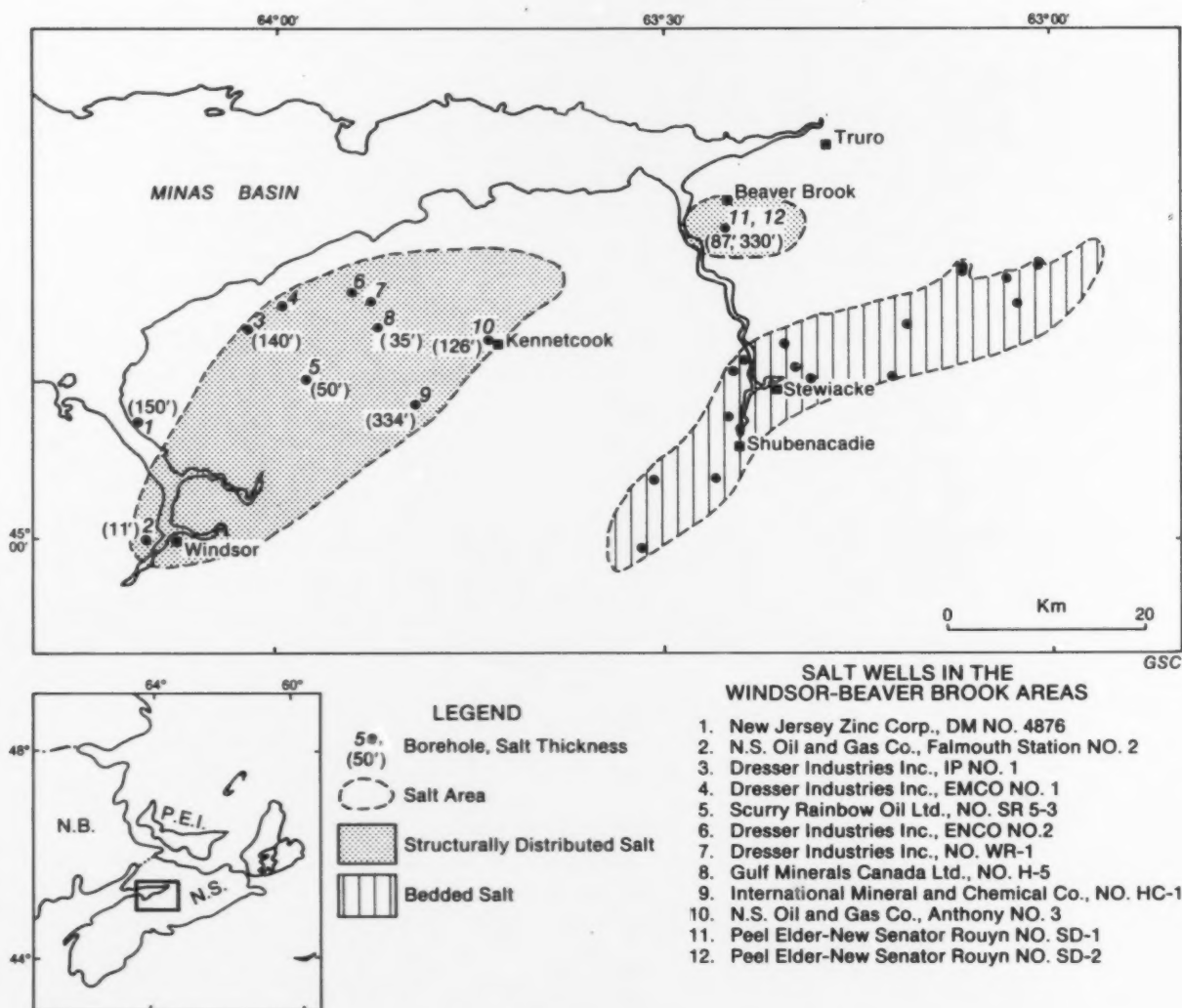


Figure 3. Distribution of Windsor-Group salt in the Windsor-Truro area of Nova Scotia.

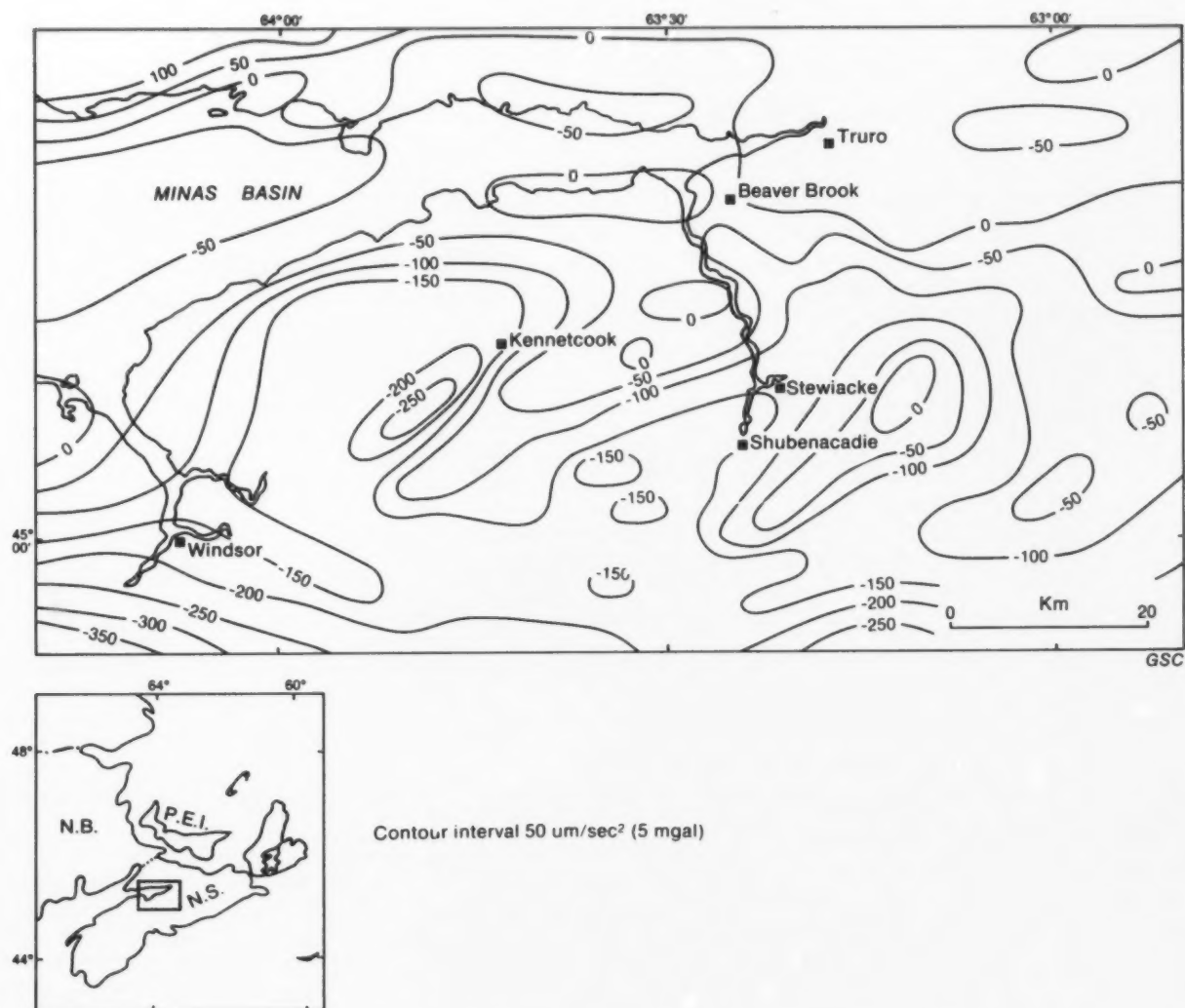


Figure 4. Bouguer Gravity Anomaly map of the Windsor-Truro area, Nova Scotia (adapted from Keppie, 1979).

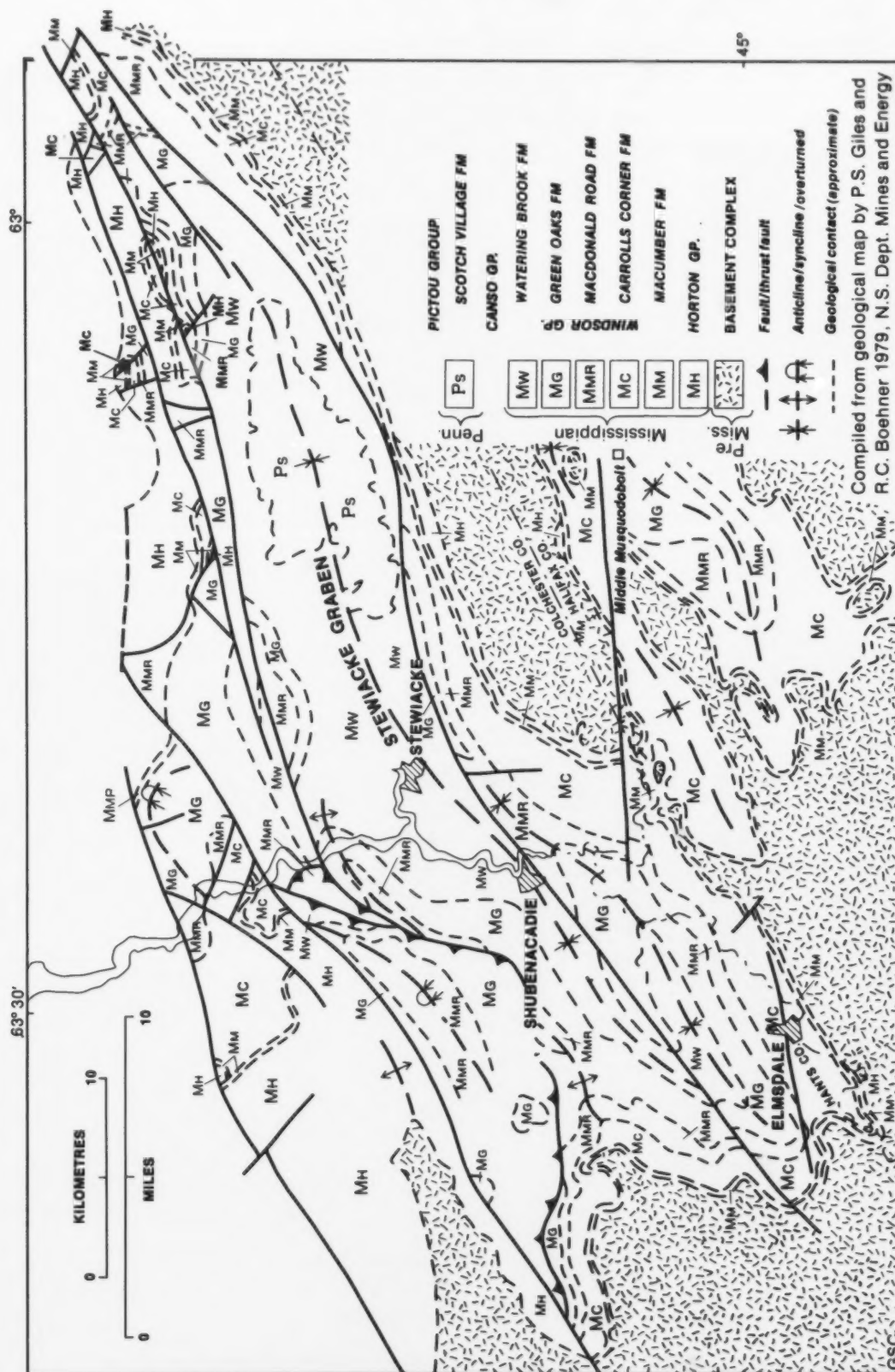
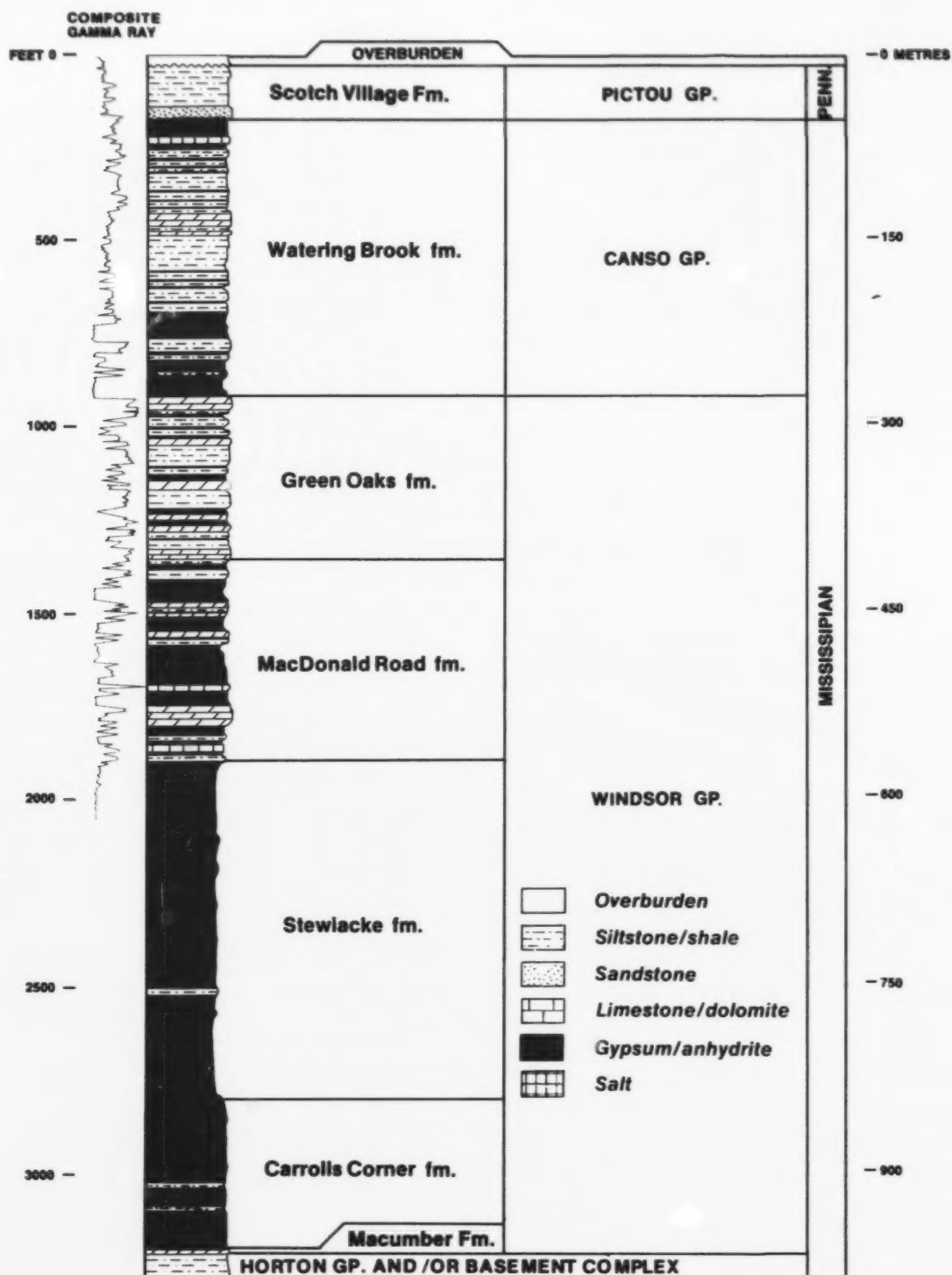


Figure 5. Geological map eastern Minas subbasin, Nova Scotia.



Informal names from Giles, and Bochner, 1979;
gamma ray log adapted from St. Joseph Explorations Ltd.

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Figure 6. Composite Mississippian and Pennsylvanian successions, Minas subbasin, Nova Scotia.

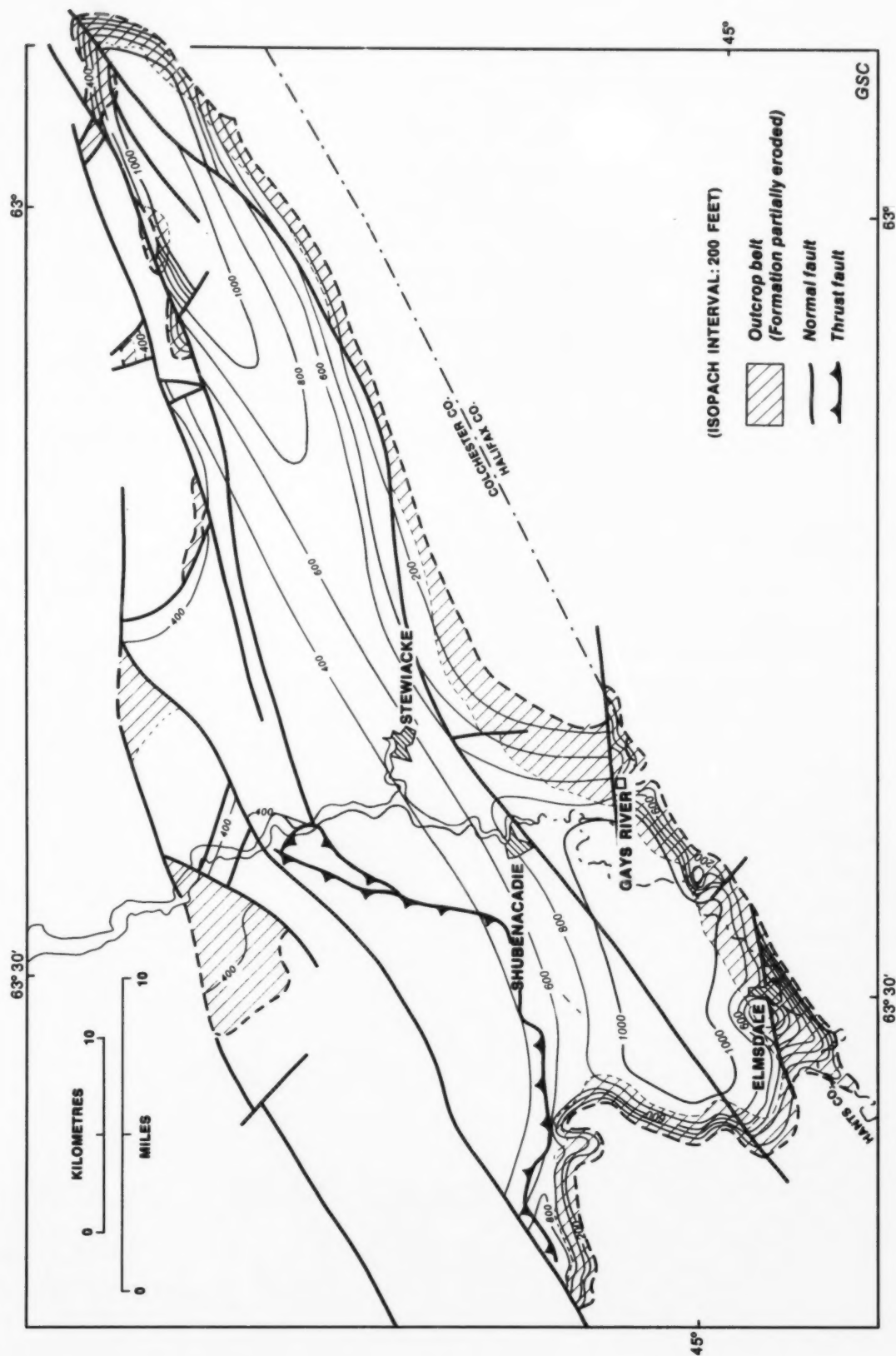


Figure 7. Isopachs of Carrolls Corner formation, Minas subbasin, Nova Scotia.

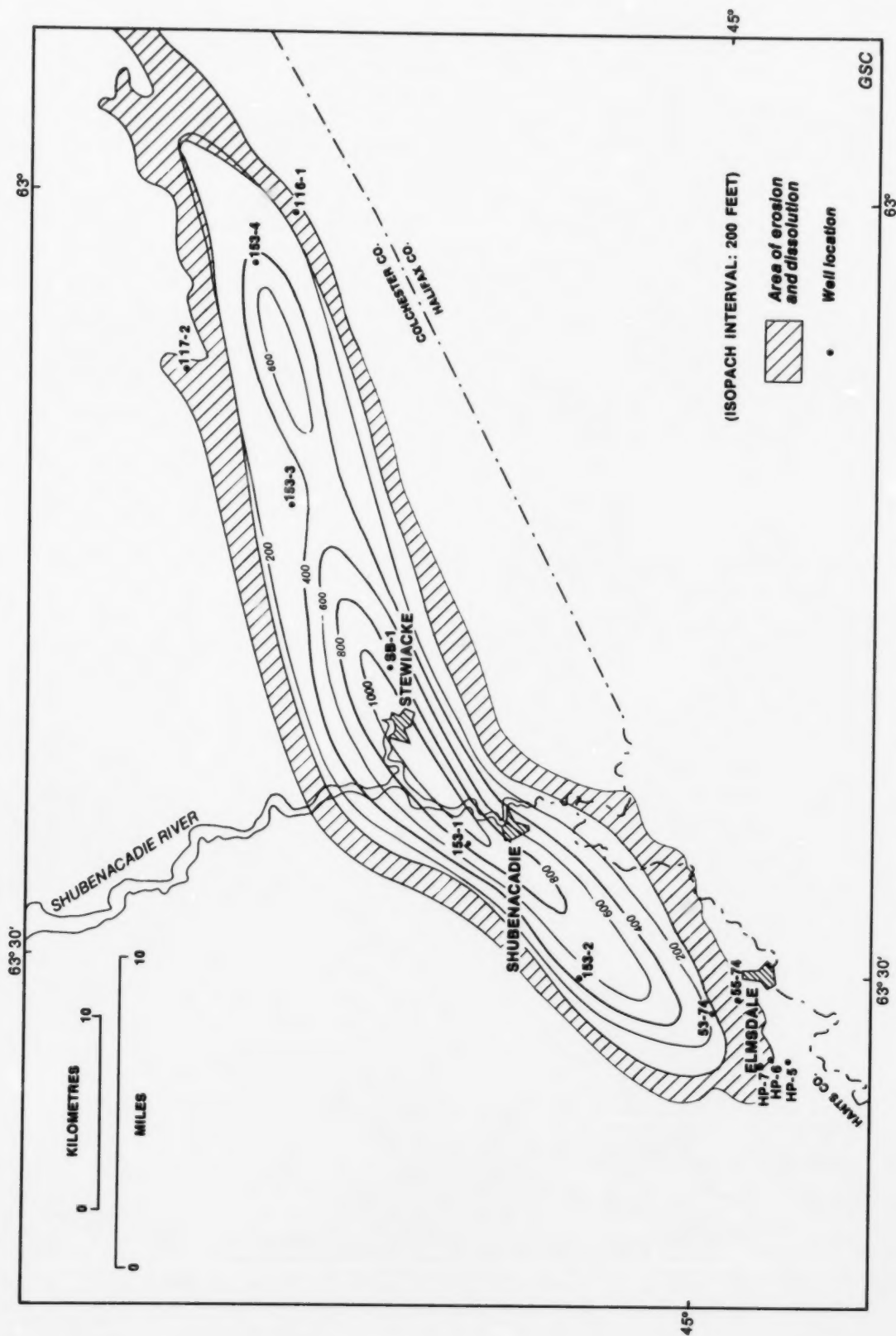
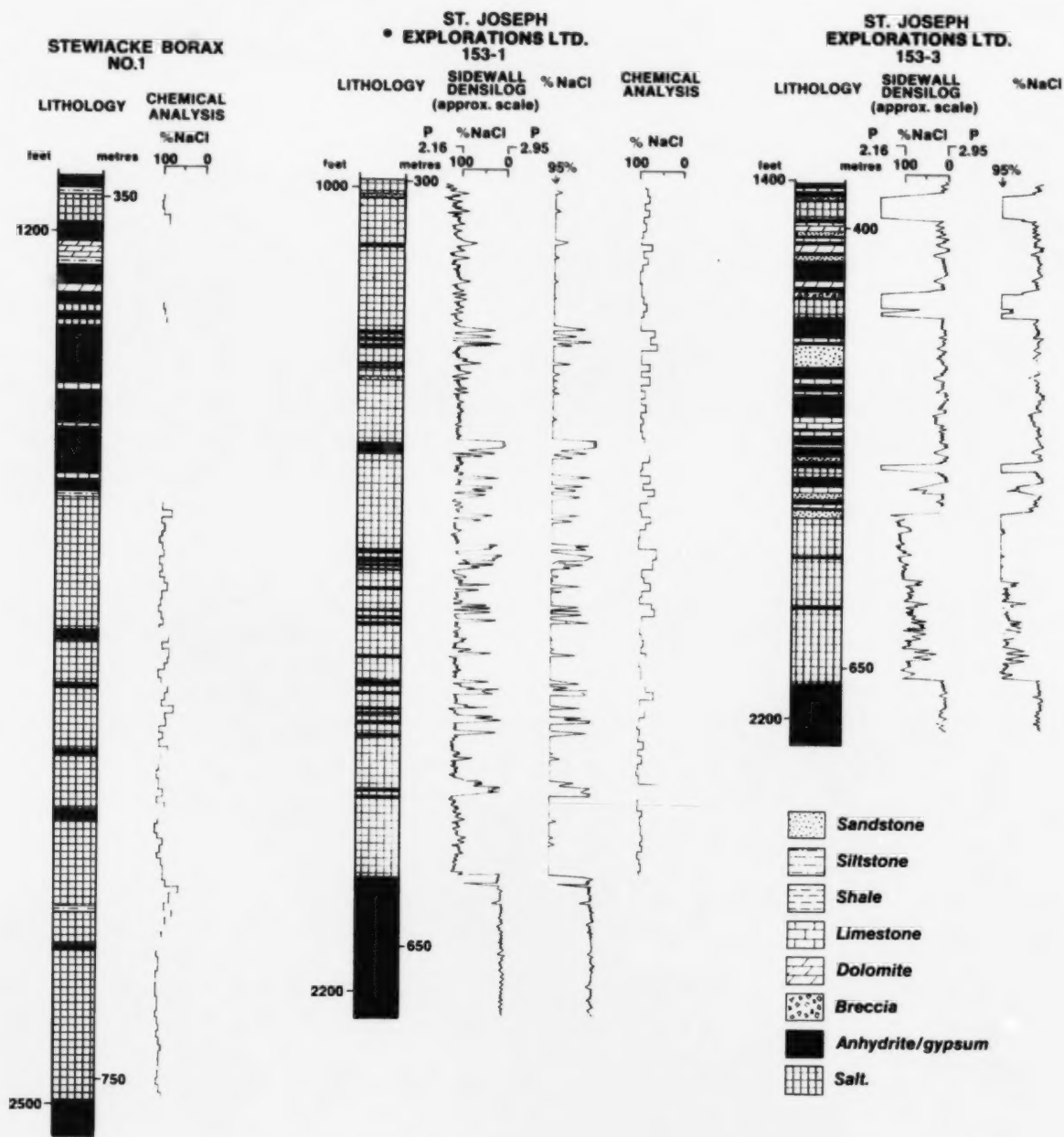


Figure 8. Isopachs of Stewiacke formation, Minas subbasin, Nova Scotia.



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Figure 9. Stewiacke formation salt analysis from three boreholes, Stewiacke graben, Minas subbasin, Nova Scotia (Chemical analysis run by Nova Scotia Technical College).

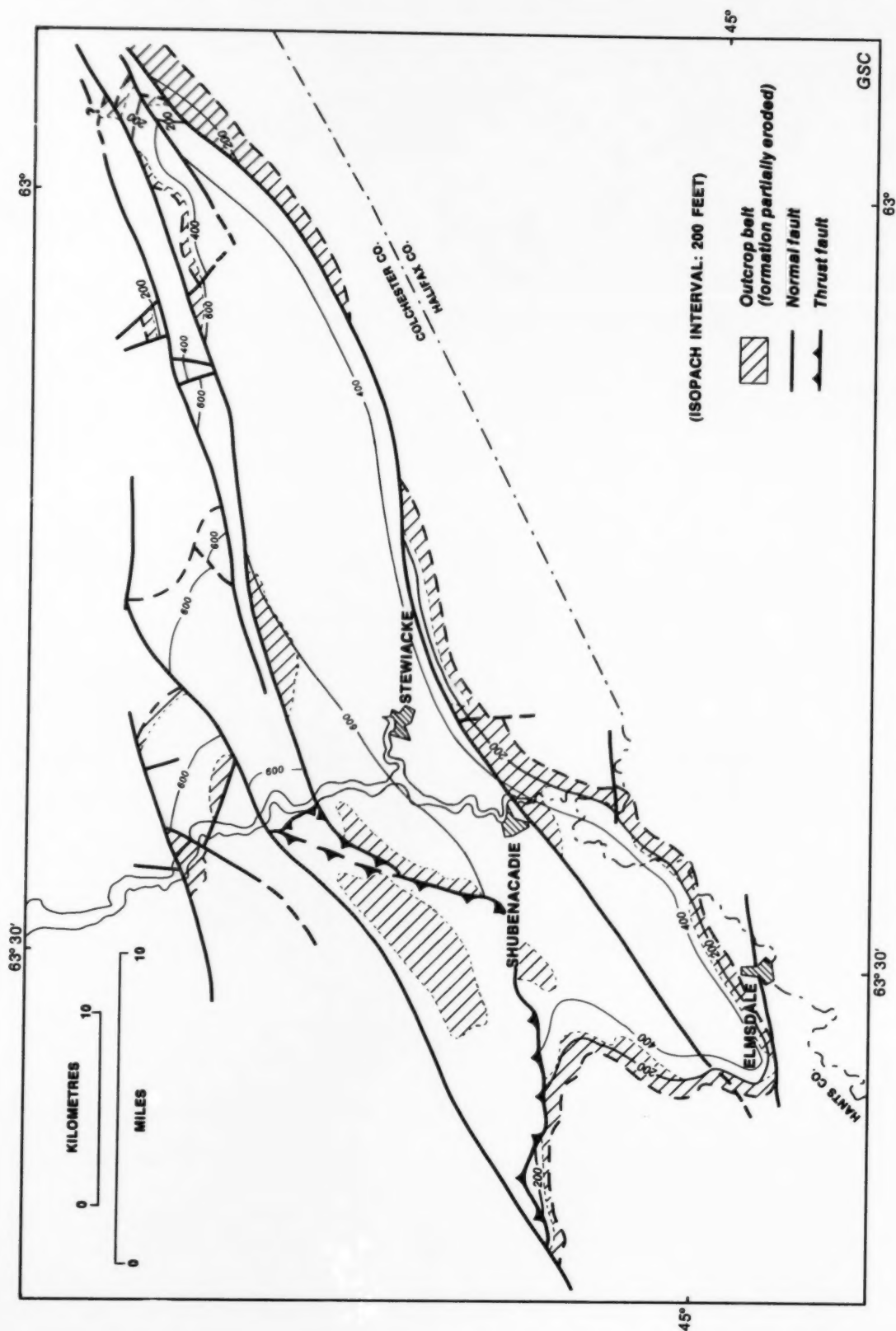


Figure 10. Isopachs of MacDonald Road formation, Minas subbasin, Nova Scotia.

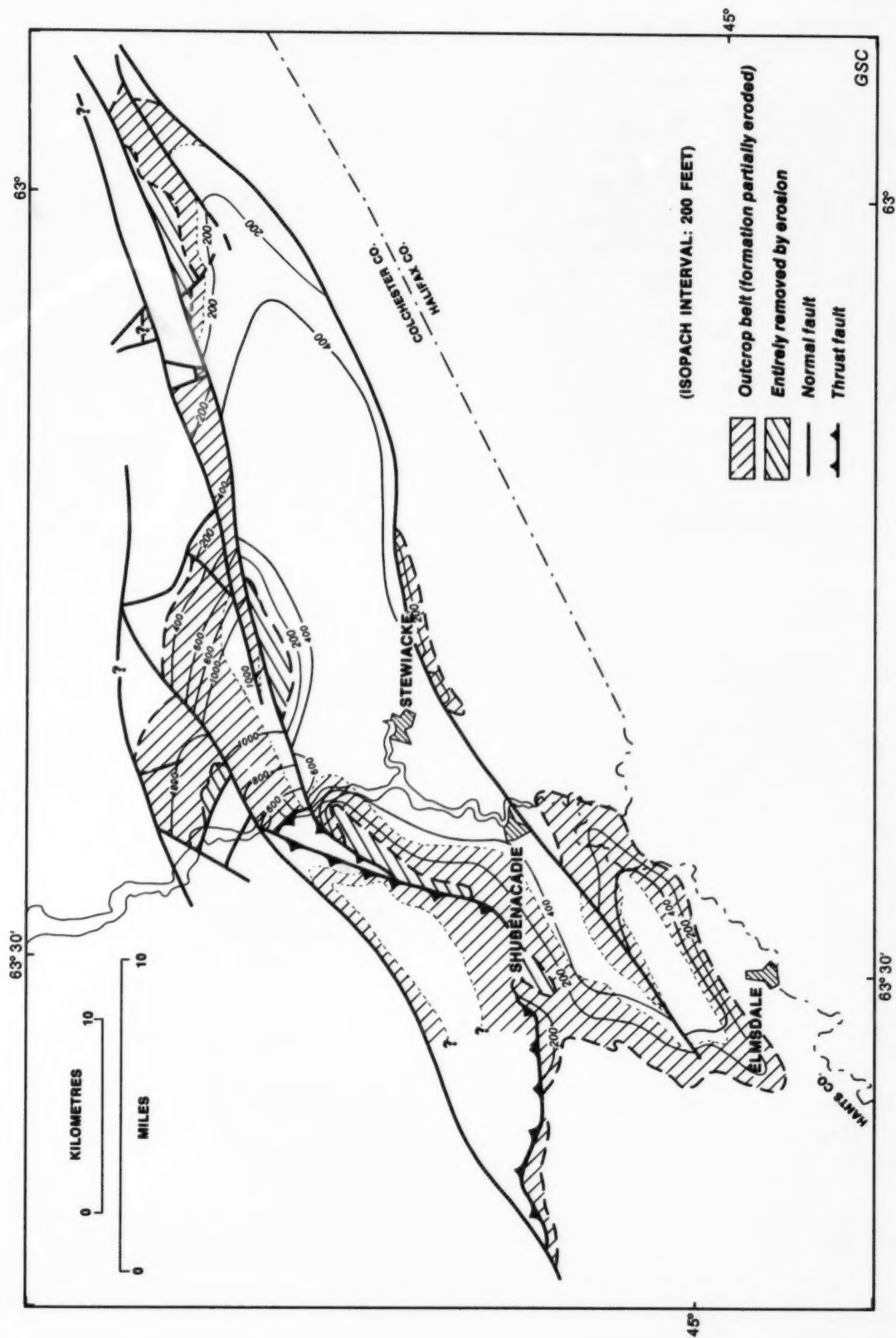


Figure 11. Isopachs of Green Oaks formation, Minas subbasin, Nova Scotia.

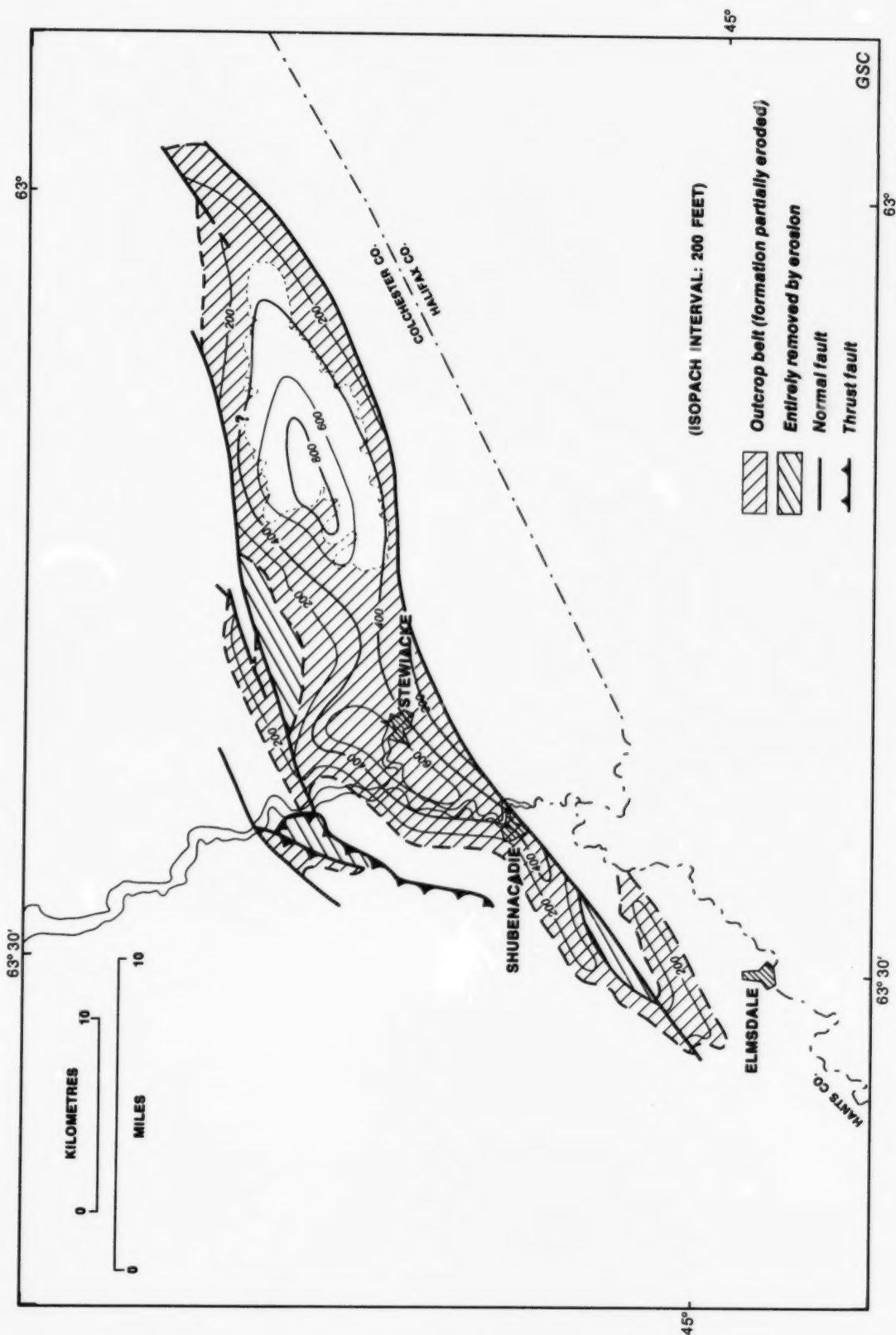


Figure 12. Isopachs of Watering Brook formation, Minas subbasin, Nova Scotia.

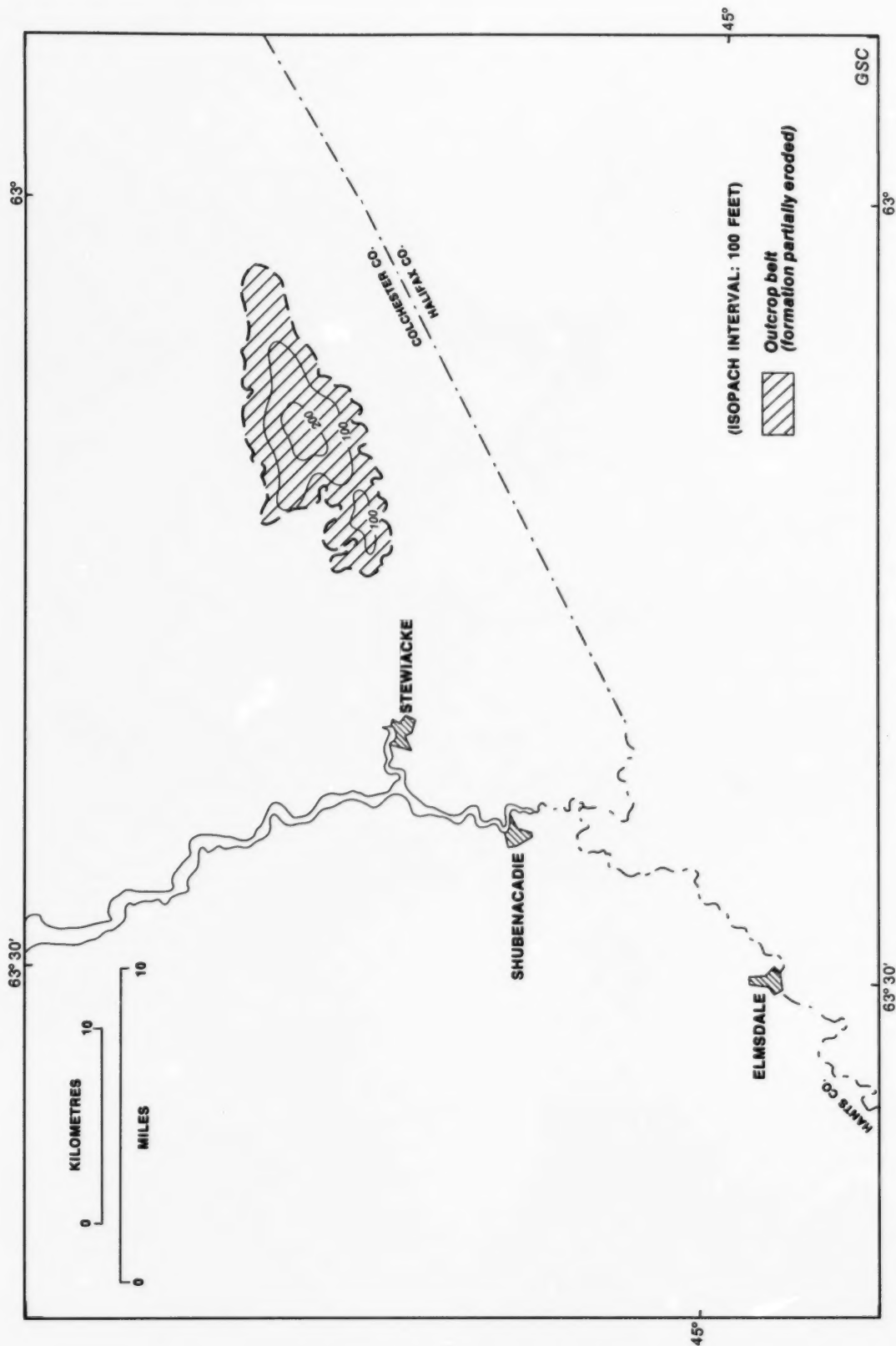


Figure 13. Isopachs of Scotch Village formation, Minas subbasin, Nova Scotia.

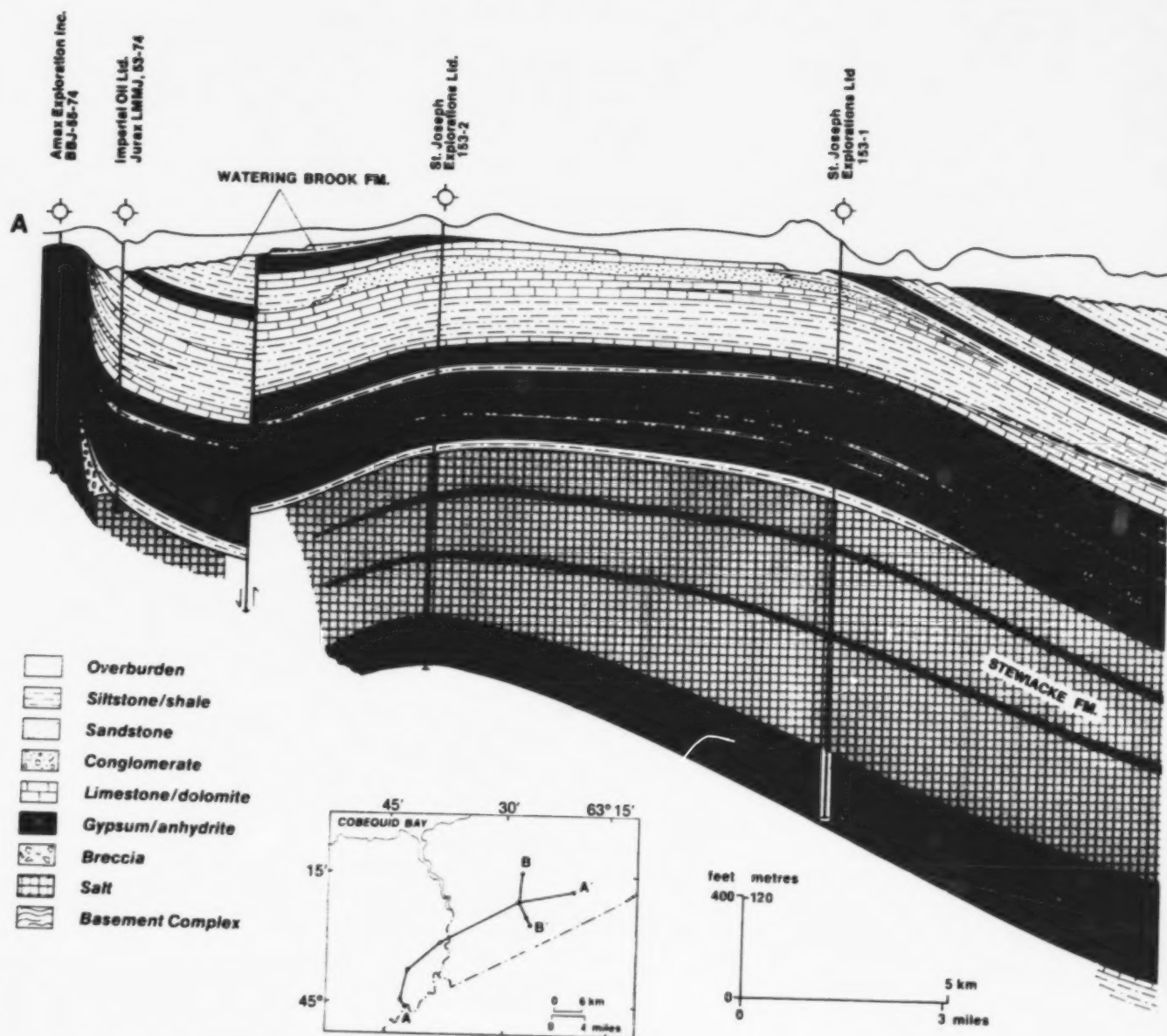
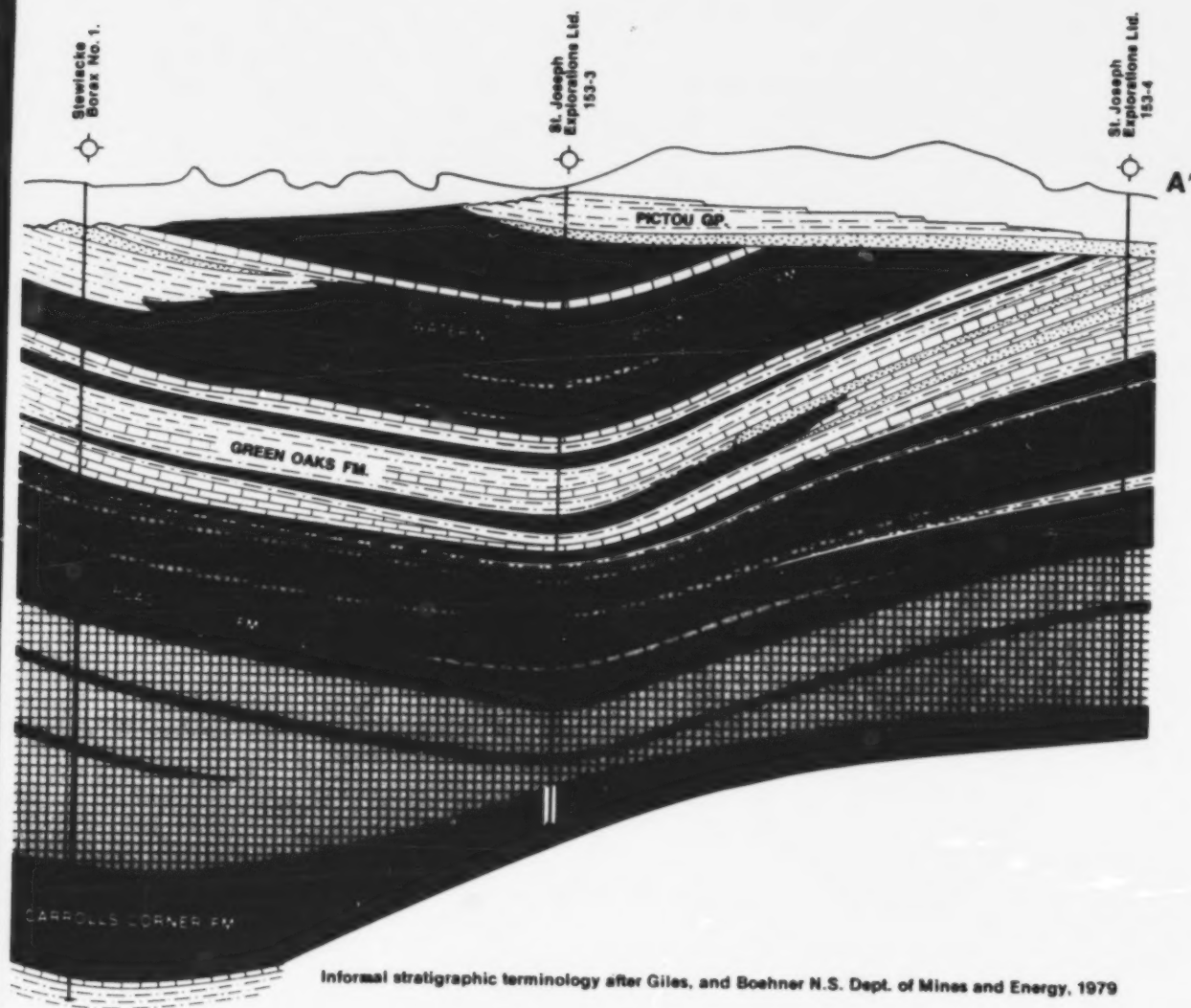


Figure 14. Cross-Section A-A', Minas subbasin, Nova Scotia.



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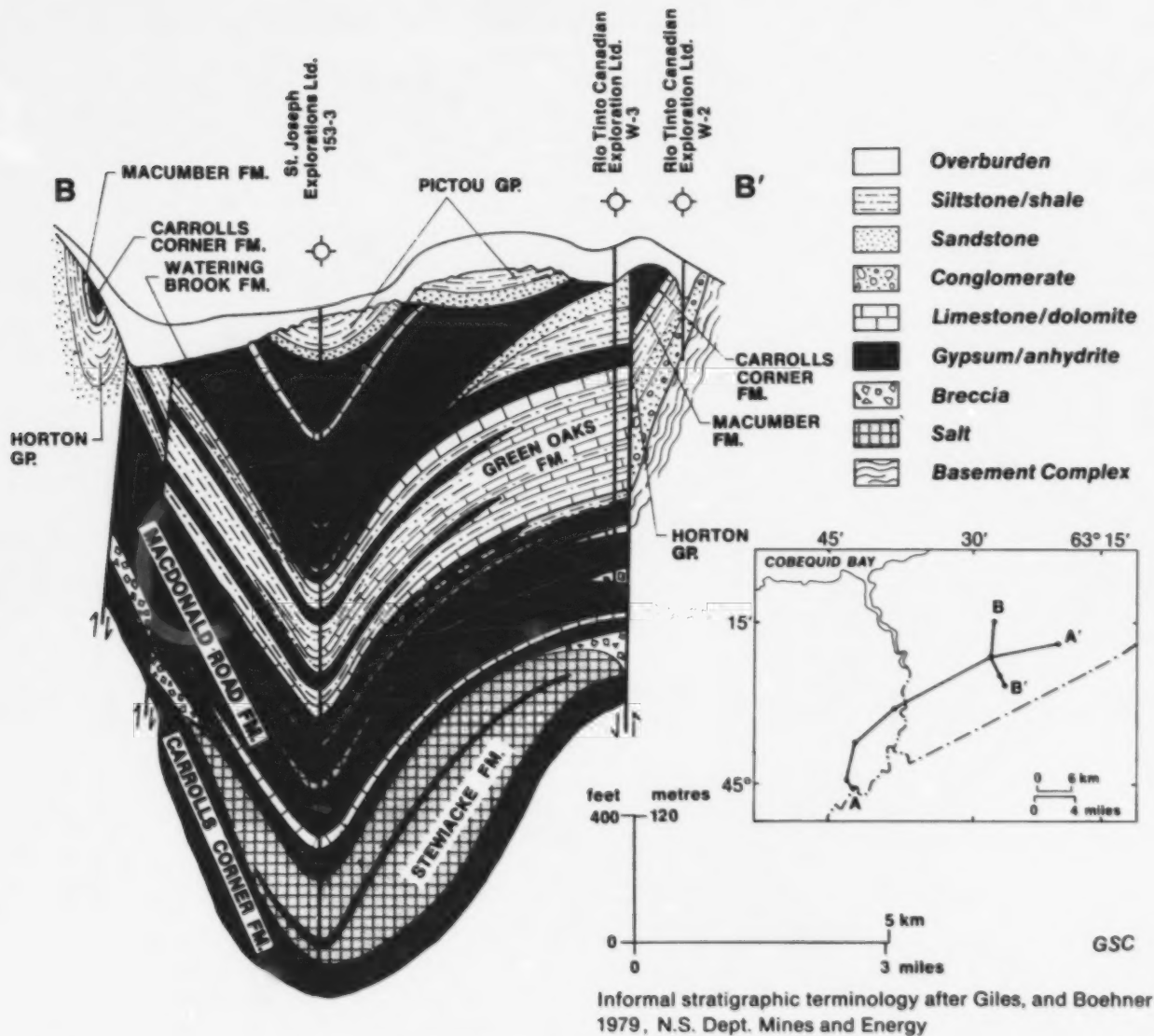


Figure 15. Cross-Section B-B', Minas subbasin, Nova Scotia.

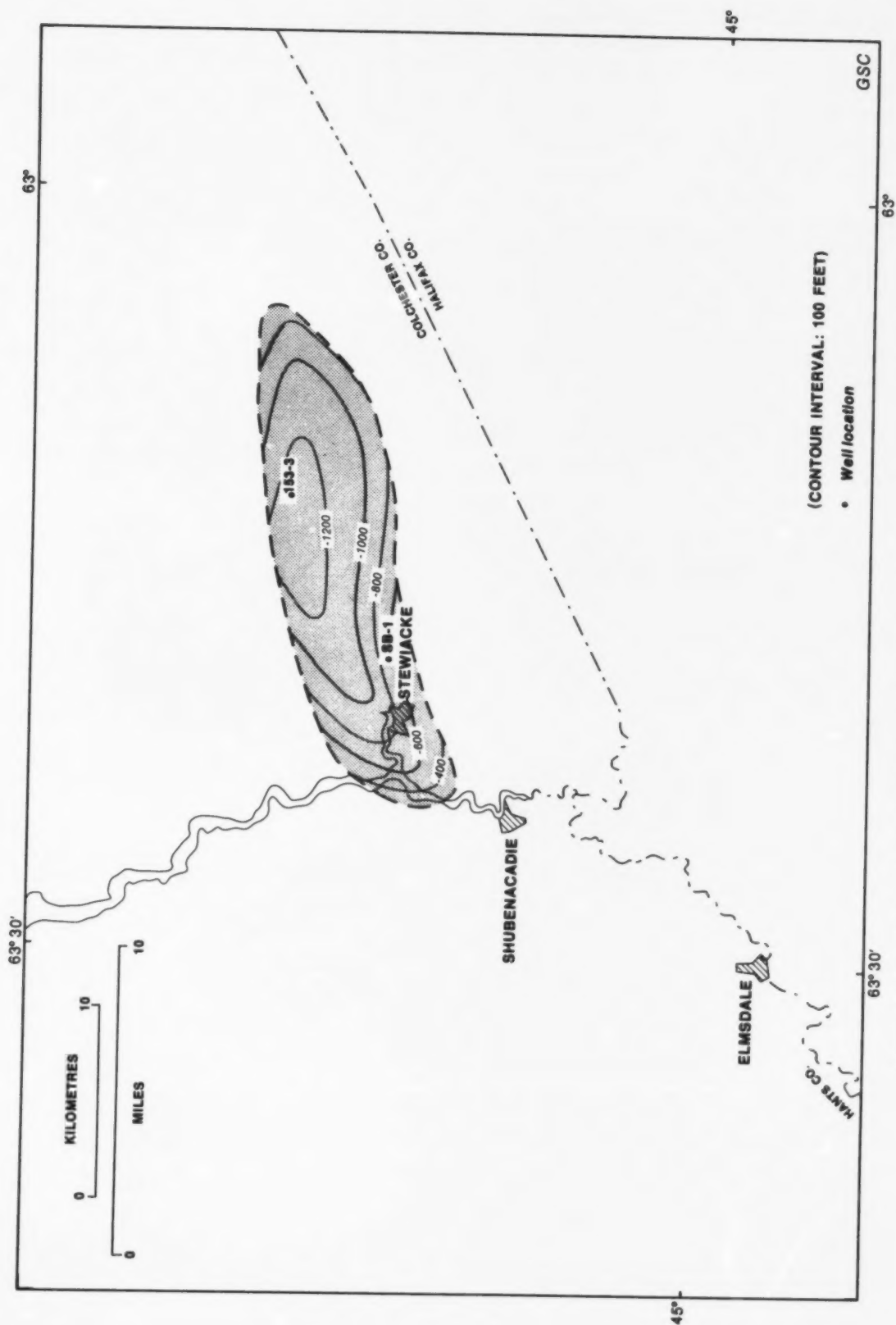


Figure 17. Structure contours on upper salt MacDonald Road formation, Minas subbasin, Nova Scotia.

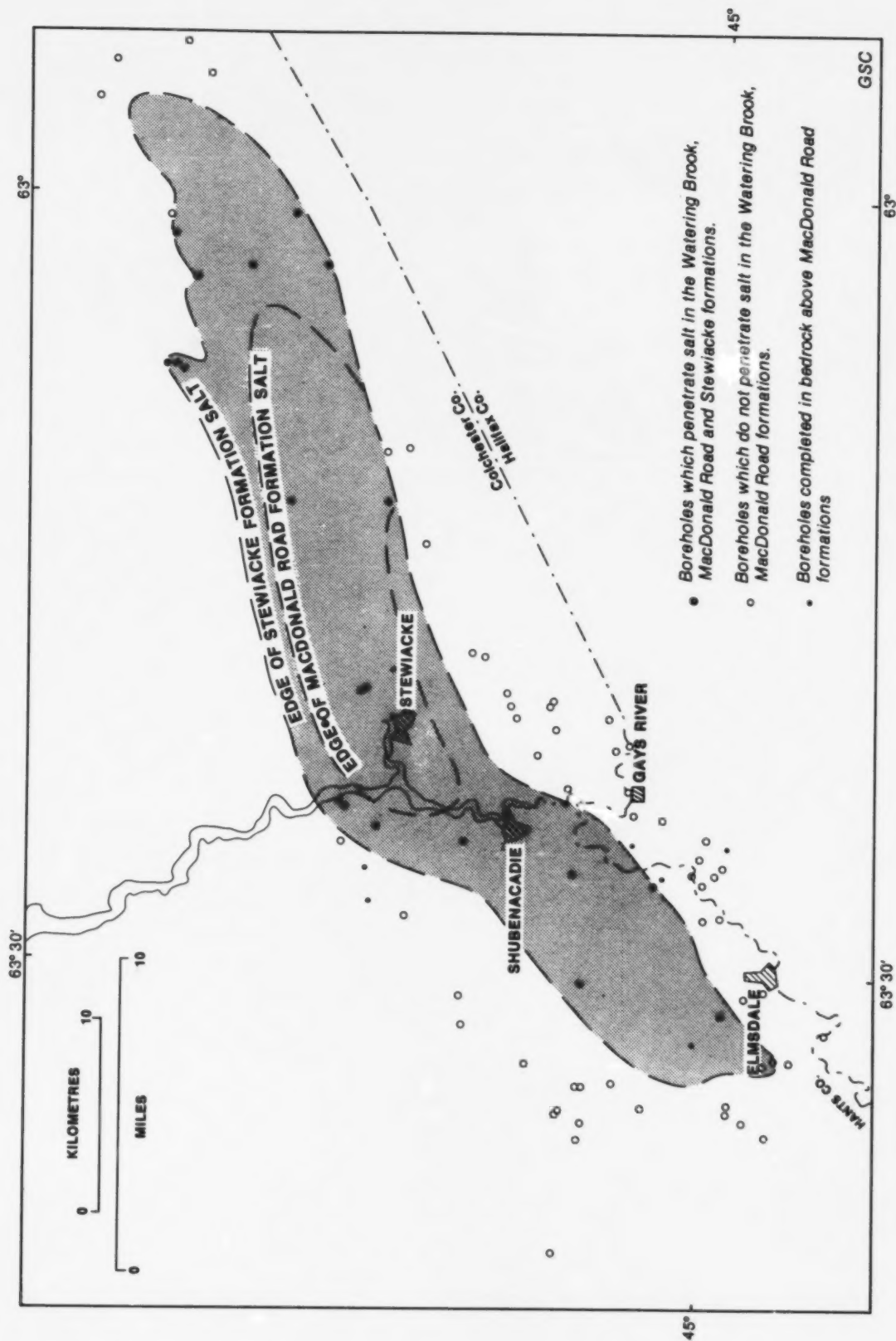


Figure 18. Borehole locations, Stewiacke area, Minas subbasin, Nova Scotia.

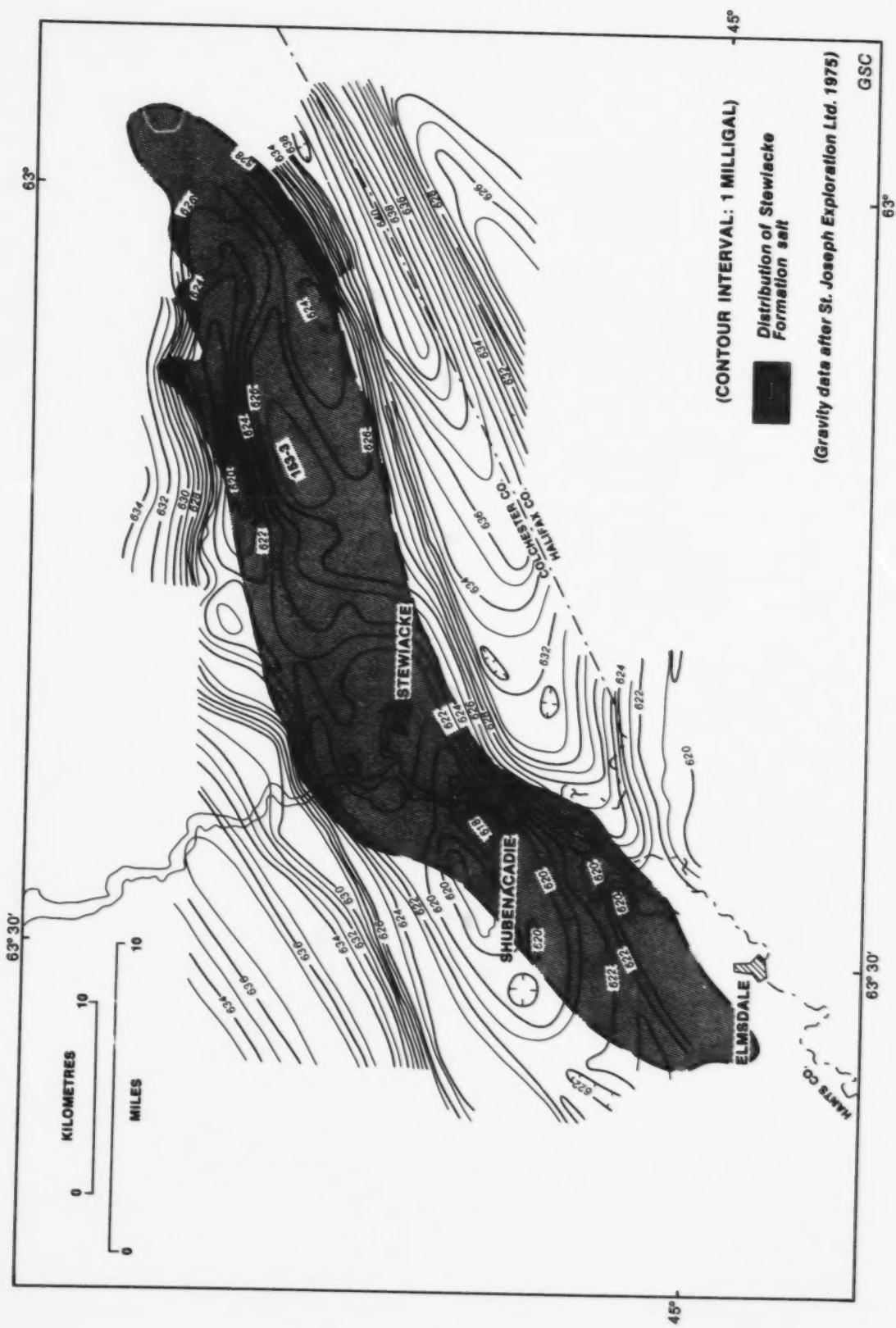


Figure 19. Gravity map, Stewiacke area, Minas subbasin, Nova Scotia.

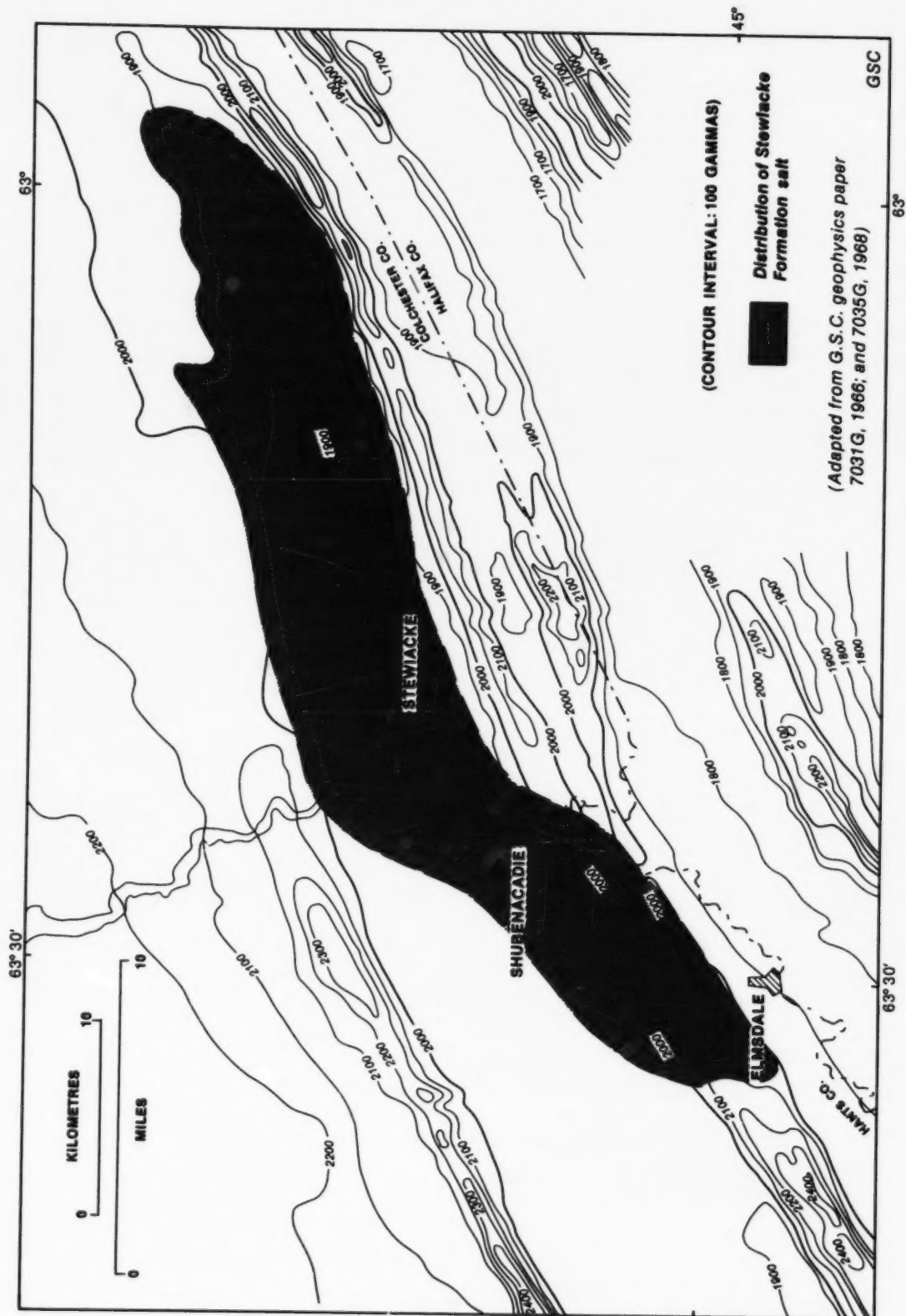


Figure 20. Aeromagnetic map, Stewiacke area, Minas subbasin, Nova Scotia.

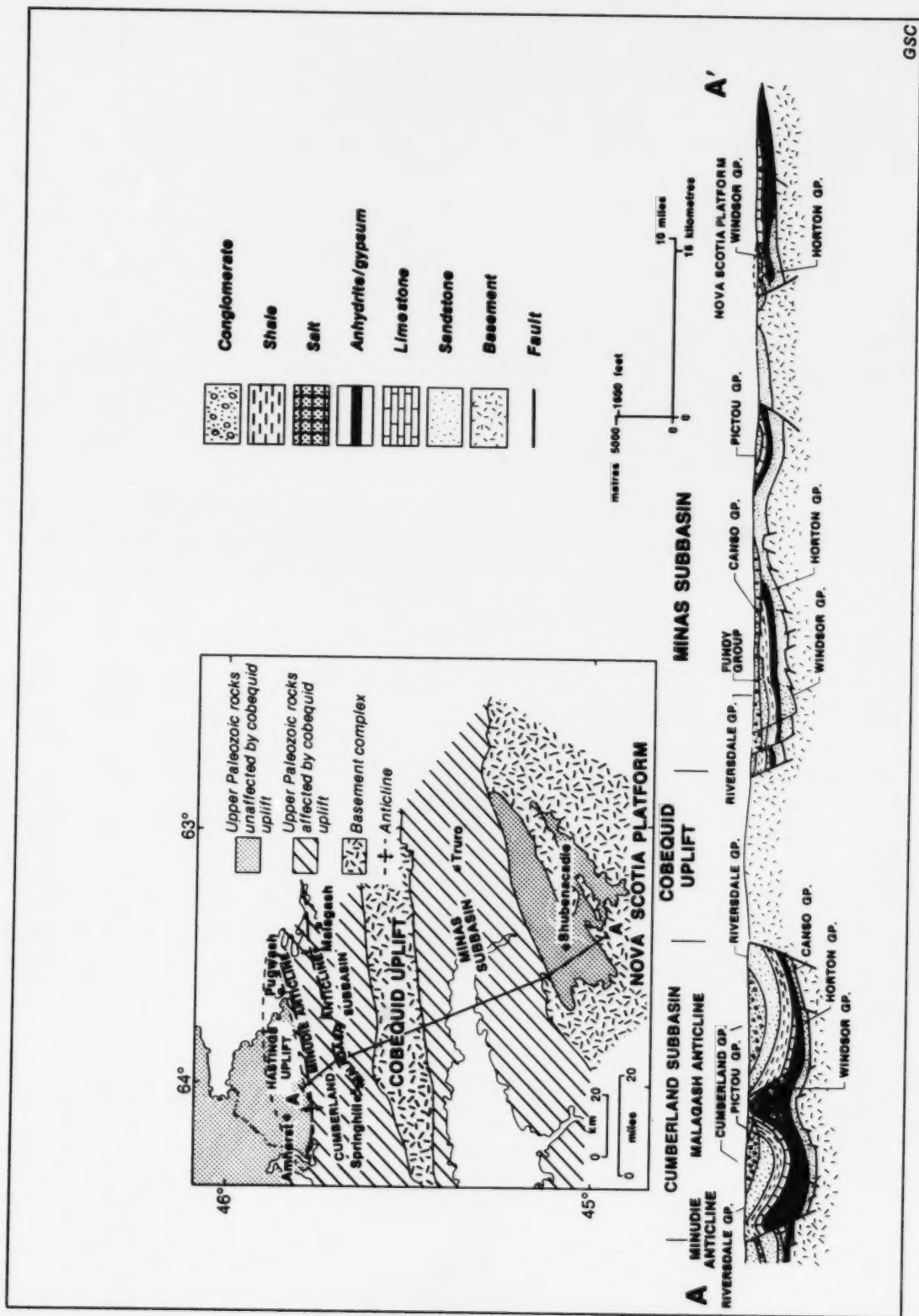


Figure 21. Effects of Maritime disturbance on the Cobequid uplift and adjacent areas.

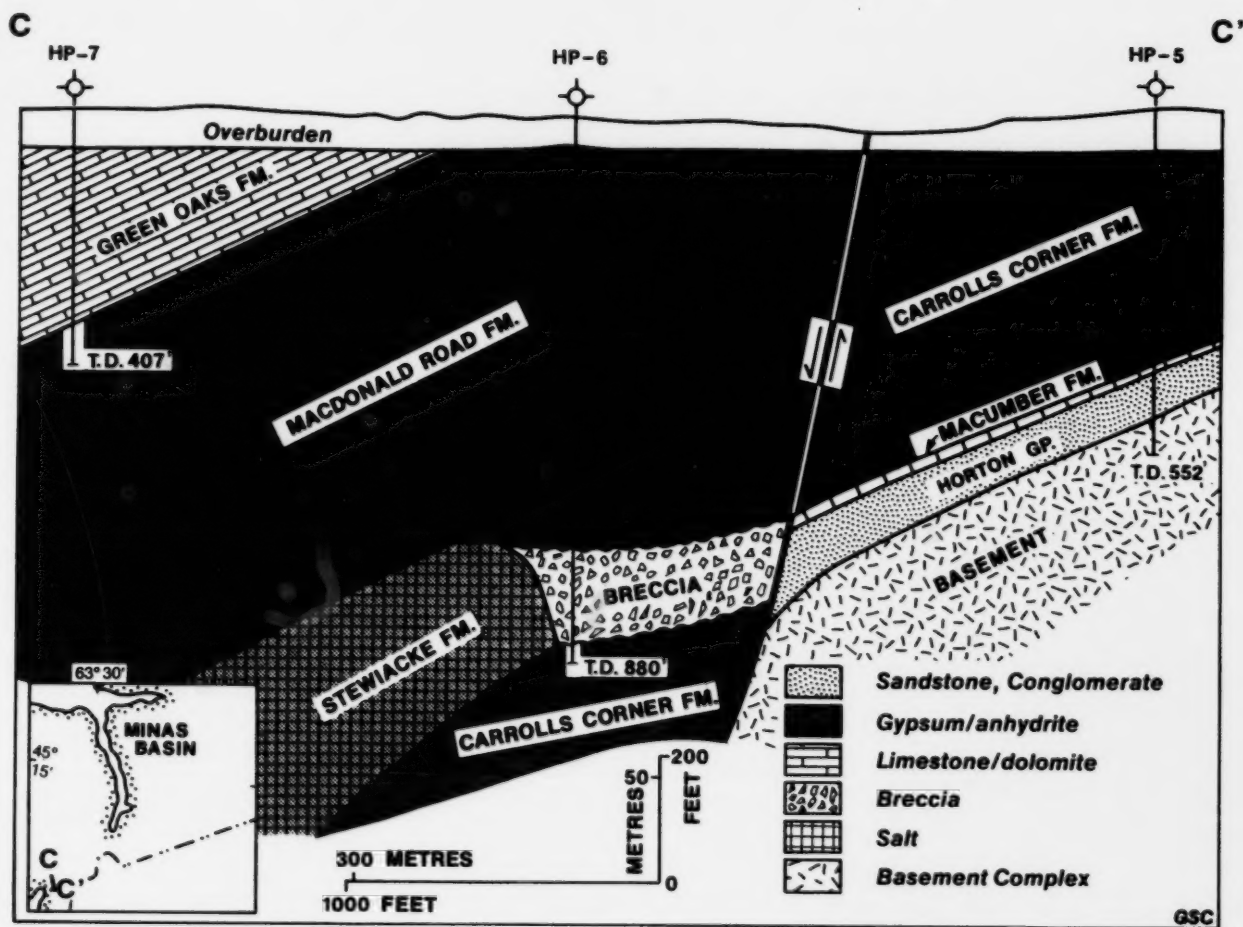


Figure 22. Salt dissolution model, Stewiacke graben, Minas subbasin, Nova Scotia.